# TECHNOLOGY APPLICATIONS
# SEMI-ANNUAL PROJECT REPORT

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
The Technology Utilization Office
(Code KT)

for the period

1 June 1970 to 30 November 1970



NASA Contract NASw-2055

January 1971

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Submitted by

Biological Sciences Communication Project

The George Washington University Medical Center

2001 S Street, N.W., Washington, D.C. 20009

January, 1971

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# INTRODUCTION

# INTRODUCTION

In response to recognition that much of the technology developed to meet aerospace needs is potentially applicable to broader public needs, the NASA Technology Utilization Office has sponsored the development of mechanisms for facilitating a systematic, continuing transfer of technology.

A major emphasis in the development of TU programs has been placed on establishing viable methodologies and mechanisms for both ensuring successful transfer and providing appropriate visibility for both technical substance and procedure.

This report is intended to provide a qualitative overview of the Application Team Program, one of the major operational programs sponsored by the TU Office. In this activity, NASA sponsored Teams are cooperating with over 100 organizations, professional groups, medical research and clinical centers in joint problem-solving efforts which facilitate application of aerospace developments and expertise for broad public benefit. The report attempts to provide a description of the total context in which these technology transfer efforts are occurring.

The first part focuses on the context of some of our complex society's needs. The emphasis here is to describe significant problems for which applications of new or improved technology are being sought.

The second part of the report reviews a number of areas of technology in which NASA has made significant contributions. These areas of technology along with many others provide the immense base of knowledge which has proven to be of value in the non-aerospace context. The NASA Applications Teams regularly tap these technologies in the search for solutions to non-aerospace problems.

The third part of the report describes the Applications Team Program. Specific achievements of the Applications Teams during the 6-month period covered by this report are described in the fourth and fifth parts. The results of some significant technology transfers are not included, since the technology recipients wish to make initial publication of their research results. These transfers will be described in later reports in order to maintain privileged relationships developed between the Applications Teams and the biomedical or public sector researchers.

The sixth part of the report discusses several program support activities designed to assist NASA and the Applications Teams in their technology transfer efforts.

The seventy part of the report discusses those facets of the Applications Team Program methodology which will receive continued emphasis in the future.

The appendices discuss steps taken to further improve the wide variety of experimental methodology used by the Applications Teams.

Requests for further information on items or concepts contained in this report should be directed to:

Director
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Code KT
National Aeronautics and Space Administration
Washington, D. C. 20546

# TECHNOLOGICAL REQUIREMENTS IN THE NON-AEROSPACE (PUBLIC) SECTOR

## TECHNOLOGICAL REQUIREMENTS IN THE NON-AEROSPACE (PUBLIC) SECTOR

### BIOMEDICAL SECTOR NEEDS

During the past decade, the costs of quality medical care have risen steadily and steeply, and the cost of hospital care is now rising at a rate twice that of other cost-of-living categories. The growing population, the rising expectation of the general public for improved health care, and a larger elderly population place severe strains on the present health care delivery system. An increasing proportion of high-quality medical care is in a few medical centers, and emergency medical services have deteriorated severely or are nonexistent in many urban and rural areas. These problems will not be solved merely by supplying more doctors and nurses. There is need for a comprehensive review of the situation and the introduction of new skills and new technologies; these would probably bring about a restructuring of the entire system for health care delivery in the United States. Throughout the country there is obvious need for intensification of the often feeble efforts to apply technological capability to the solution of health service problems.

The life expectancy in the United States is still below the age of 70, essentially unchanged since 1949. The life expectancy of males is now in 22nd place among the countries of the world and the life expectancy of females is in 10th place. This relatively low U.S. position is due, in part, to the high mortality rate of men in their 40's, in part, to the high infant mortality rate, and in part it is a result of the wide variation in the quality of medical care available to different portions of the population.

The national infant mortality rate, about 24 deaths during the first year per 1000 children born alive, is almost twice that of Sweden and the other Scandinavian countries. This rate falls far below that of the majority of developed nations. These discouraging figures find their basis, in part, from a lack of participation in the health care system of major segments of the population. In New York City, during 1966, approximately 40 percent of the women who gave birth had not seen a doctor during pregnancy. By contrast, in Scandinavian countries medical assistance is regularly available to expectant mothers and a midwife system is common; yet there is a severe shortage of doctors in Scandinavia whose citizens visit a physician only on the average of three times a year whereas in the U.S. the average is five visits per year. Thus, it might be inferred that a small percentage of Americans is over- utilizing the limited supply of physicians and health facilities. While this program is often considered to be socio-economic in nature, it may be partially alleviated by technologies which permit better usage of current medical and clinical resources.

Expansion of General Health Care Capability. An obvious necessity exists for the expansion of health care delivery systems to take care of a large segment of the population in rural and low population density areas, as well as those in central cities. A key issue is that many remote areas lack an economy sufficient to support an active medical profession, hospitals, nurses, ambulances, and other essential components for adequate health service systems.

As an example, the seven southwestern counties of New Mexico which cover 32,000 square miles form an area larger than the combined five New England states. While the estimated population of the New Mexico area is over 130,000, if the population of the five largest towns is excluded, the population density would be less than one person per square mile. There are 68 medical doctors in this area but 33 are located in the largest town, and transportation is difficult.

A system is being developed to meet these problems, which will bring both routine and emergency medical care to people beyond the reach of the limited supply of physicians. Paramedical personnel and nurses could connect medical instrumentation to the patient. As visual information can be vital to a proper diagnosis, a television camera would enable a remote physician to observe the patient as well as to review the patient's physiological indicators, while the physician, at the same time, guides the testing of the patient and consults computer stored medical histories. If necessary, the physician would recommend action to be followed such as administration of a drug or simple suturing by the trained paramedical personnel. If there is need for the patient to be transported by helicopter to a centrally located hospital, during transit, biomedical telemetry systems could transmit his vital parameters to the hospital so that precious time would not be lost in initial diagnosis.

Another major approach to providing improved medical services to the urban community is the automated multiphasic health testing (AMHT) center. These centers utilize paramedical personnel in conjunction with medical instrumentation to assess an individual's physiological condition. The primary purpose of multiphasic screening is to provide an early warning system, to alert people to disease conditions of which they may be unaware. Medical electronic instrumentation and automated systems for blood analysis would allow a trained technician to perform many complicated tests economically, accurately, reliably, and rapidly. When coordinated with a remote information processing facility, these instruments permit relatively small, localized, economically operated facilities to provide preliminary patient screening in both urban and remote rural areas. Records are entered automatically into the patient's computer memory record, along with information on his medical history and on his physical condition at the time of diagnosis. The computer then compares the test results with the normal ranges for age and sex to

determine if an abnormality exists. If an abnormal condition is identified, the patient can be referred to a physician for more thorough diagnosis and treatment. By reducing the average time and cost per test, a comprehensive physical examination can be performed at a moderate cost.

Patient Monitoring. Intensive monitoring of patients in critical or near-terminal conditions is gaining rapid and wide-scale acceptance in hospitals. Continuous monitoring of the physiological variables of post-operative or critically ill patients (also premature infants) allows opportunity for better care and a substantial reduction in mortality rates. Such monitoring systems can record changes in many physiological variables, can note and analyze their progression, and alert the medical personnel in case any of the monitored parameters fall outside a predetermined range of values. The systems can also control life-support devices. Technological requirements are apparent for improved, non-invasive sensors and transducers, an improved data transmission capability, and more highly analytical data processing systems, for further development of this vital function.

Cardiovascular diseases cause 54 percent of all deaths in the United States according to current statistics. More than 150,000 persons apply annually to the Social Security Administration for disability pensions because of cardiovascular disorders. A major portion of medical research is focused on developing, understanding, and treating cardiovascular diseases. New or improved technology is urgently needed to support cardiac research and related therapy. Artificial pacemakers are making it possible to sustain the lives of 13,000 patients per year suffering from heart block or chronic heart rhythm disturbances. While the current technique for pacemaker electrode installation requires a major surgical procedure, a new alloy may allow the electrode to be implanted in the heart muscle through a hypodermic needle inserted through the walls of the chest and heart. A technique of carotid nerve stimulation, developed by NIH, that obviates or provides rapid relief from agina attacks will be enhanced by a NASA-developed biologically compatible flexible electrode. Techniques for automating the analysis of EKGs recorded during a patient's normal daily activity will enable physicians to more accurately determine a patient's susceptibility to a heart attack, and initiate protective measures promptly.

Although angiography has been in use for several years, reading and interpreting the films produced has been a very time-consuming procedure. Impedance cardiography shows promise as a diagnostic instrument for assessing cardiac output atraumatically. Since it is far safer and simpler to use than other currently available techniques, it could, in time, replace them. Computerized pattern-recognition techniques are being applied to cineangiography to determine the efficiency of a patient's heart action. The utilization of this technique will probably be expanded.

Pulmonary disease is the basis of claims of about 50,000 people per year who apply to the Social Security Administration for disability pensions. Onset of the disease often occurs when claimants are in their 30's and the average total pension paid throughout the lifetime of one so diabled approximates $70,000. Evidence currently suggests that a great deal of progressive lung function impairment could be retarded or even prevented by timely and consistent treatment. A significant part of the problem is in determing the existence and the extent of pulmonary impairment. Similarly, it is necessary to judge the therapeutic value provided by various techniques. The most widely used methods for examining respiratory function are bulky and cumbersome and prevent ehe patient from moving about or exercising in a normal manner. Several new techniques, which allow the patient to move about or exercise essentially unencumbered, are beginning to be widely used clinically and further widespread use could significantly affect the lives of numerous patients.

Impedance pneumography is a technique which, when used with a small transmitter, will allow a physician to measure the volume of air inhaled and exhaled, the inspiration and expiration patterns, and the respiration rate while the patient is engaged in any type of activity or exercise. The instrumentation package could be worn by the patient on a belt or carried in a shirt pocket. Miniature high-speed mass spectrometer systems, may enable a physician to determine the efficiency with which respiratory gases are absorbed and released by the lungs. Precision, low resistance flowmeters could also make a valuable contribution to the study of the patient's pulmonary condition. Utilized in a comprehensive, systemized care program, such devices will enable therapists to determine with greater accuracy the efficacy of the various types of available treatment.

Respiratory disorders also contribute significantly to the high infant mortality rate. However, respiratory function monitoring devices developed for use on adults would not always be adaptable to infants. Several systems have recently been developed specifically for infant monitoring, which could reduce the mortality rate associated with respiratory malfunction. In regard to infant respiratory function there is need occasionally to place an infant in an atmosphere with a high oxygen concentration. While this may be necessary for only a few days, if the oxygen content of the respired air is too great for too long a time, such a situation can result in permanent blindness. A small oxygen concentration monitor has been developed which can measure the amount of oxygen in the air being delivered to the infant. Originally designed to monitor the atmosphere of a space capsule, the device is now commercially available. Its ability to immediately warn nursing personnel of excessive oxygen concentration should significantly reduce the number of children blinded by a prevalent situation.

Surgery. New and more complicated surgical techniques are evolving. The amount of time that the patient is on the operating table as well as

the time he is under anesthesia are increasing. Hence, of great importance are more rapid, accurate, continuous techniques to assess the depth of anesthesia and the physiological condition of the patient. Anesthesiologist's responsibilities are becoming greater, which necessitates a search for new methods and instruments as aids.

Most patients undergoing major surgery require mechanically assisted respiration and the anesthesiologist is charged with the duty of administering respiration as well as providing a steady flow of anesthetic gases. Continuous accurate information on the chemical composition as well as the flow rate and volume of respired gases could greatly enhance the anesthesiologist's ability to monitor and control the patients' condition. This would significantly enhance the patients' chances of survival. An accurate flowmeter and fast-reading mass spectrometer originally developed for the space program may provide such needed information to the anesthesiologist.

Clean room technology developed for the sterile construction of spacecraft hardware and adapted to the operating room helps to improve and maintain sterile conditions, thus reducing risk of dangerous infections. Methods developed for the space program can be adapted to hospitals permitting continuous monitoring of the quantity of bacteria and particulates in areas aiming for sterility, such as operating rooms, providng further protection from infection.

Rehabilitation of Handicapped. The Department of Health, Education, and Welfare estimates that 12 million Americans have disabilities which limit them in the kind of work they can do. These handicapped persons include 250,000 in wheelchairs, and 2 million orthopedically impaired children. Economical, self-propelling wheelchairs powered by lightweight motors and power supplies, as well as innovative devices to permit chair control, are being designed. By increasing mobility and self-confidence of the handicapped, efficient chairs enable participation in a wider range of activities.

The same small motors, controls, and power supplies are being used to power self-contained orthopedic limbs for amputees. Since these devices are active prosthetics which the wearer can use to control motion and action, they should contribute to functional rehabilitation far more than the passive cosmetic protheses used for many years. A wide range of pressure measuring devices are applicable to measuring the forces exerted on and by prosthetic limbs. Other movement-sensing devices will assist physical therapists in objectively evaluating the progress made by patients undergoing rehabilitation.

The evaluation and training of muscular control and ability is often carried out using electromyographic (EMG) equipment, which measures the electric energy generated by muscle tissue when it is exercised or moved. Improved sensors and signal processors will further upgrade the capability of this equipment. Widespread use of biologically compatible plastics

and metals to replace damaged internal organs has begun. These are valuable not only in devices such as artificial heart valves and arterial or venous shunts but also as replacements for severely damaged bones and joints.

Medical Systems Management. Computerized information techniques can improve and streamline hospital record-keeping by maintaining accurate, up-to-date files of patients' medical histories. By providing a systematic review of many physiological parameters, a physician may detect the progressive development of a disease at an early stage, rather than not detecting it until after it has reached a critical, potentially fatal stage. Computer systems can maintain records and results of clinical laboratory and radiation tests, schedule the testing of a patient to maximize utilization of hospital facilities, provide central supply and inventory control, and attend to many time-consuming, laborious, administrative tasks. This will significantly increase the efficiency of hospital personnel and operations, and time will be utilized more effectively.

Systematized management information center concepts, based on aerospace techniques developed to permit periodic, detailed reviews of project progress, will soon be applied as an aid to hospital management personnel in the control of hospital expansion projects. Such information centers have already been used in other areas to assist city management teams in building new airports, and in implementing other public works expansion programs.

Summary. The medical and engineering communities have been responsive, in part, to these and other changing needs. Early detection of disease and preventive medicine, expanded health care facilities keyed to regional requirements, and prepaid health care programs are developing medical practices geared to meet the needs of the expanding population. Physicians are beginning to delegate routine procedures to para-professional personnel, thus freeing the physician to concentrate on tasks that require his extensive and expensive background, education, training, and experience. A severe and possibly increasing shortage of trained medical personnel continues, necessitating development and exploitation of new technology to assist limited numbers of medical personnel in providing improved medical care to larger numbers of people.

The application of new technologies to urgent problems in the biomedical field is often difficult to achieve. Technological innovations must survive a maze of obstacles in the governmental, industrial, academic and medical complex in order to have some impact on the delivery of health care services. This state of affairs is complicated by a general lack of knowledge of the mechanisms by which biomedical research moves through development into more effective instrument devices and systems for health care. The task of transfer in such an environment is difficult, but the systematic effort to find, evaluate and apply new technology must continue in order to free the doctor for more humanized, effective, and hopefully, less costly care of the patient.

PUBLIC SECTOR NEEDS

In our growing economy, social and environmental conditions that were adequate in past years no longer meet today's standards or requirements. For example, in 1964 about 15 percent of the population was considered to be living at or below the poverty level. This estimate has risen to well over 20 percent, however, it should be noted that in the intervening years, the standards of measurement has also risen. Standards of housing and the urban services characteristic of former years are no longer considered satisfactory. The populace itself, spurred on by the rising economy and an awareness of advances in science and technology, continually upgrades its minimum requirements. Continuing and new unmet human and community needs result from changing social patterns and rising expectations of the populations.

The Report of the National Commission on Technology, Automation, and Economic Progress defines these unmet needs in two categories. The first is private, the needs of those living in poverty; the second is the public requirements of the total populace. The public needs (the second category) are related to the readily acknowledged problems of housing, medical care, air and water pollution, mine safety, crime, and transportation, to name some of the most urgent.

Water Pollution results primarily from the great urban and industrial expansion of recent years. While water pollution has existed to some degree for many years, economic expansion and increased social consciousness brought about notice of its effects, prompting greater remedial action in the last decade. The major sources of water pollution, industrial, municipal, and agricultural, affect the water quality through biological, chemical, and physical processes. The quality of water is determined by the oxygen content, and high waste loads dumped into water resources require large amounts of oxygen for decomposition. Such high waste loads deplete oxygen, with attendant reduction or total loss of essential fish life. The Council on Environmental Quality has stated that over 300,000 industrial plants ".. . . discharge three to four times as much oxygen-demanding wastes as all the sewered population of the United States." And further, "The output of industrial wastes is growing several times faster than the volume of sanitary sewage." The increase in sediments and nutrients can lead to rapid eutrophication of our water resources.

Thermal pollution of water, a major ecological problem, is caused primarily by the electricity generating plant. Water is used to cool the condensers; the average increase in temperature of the cooling water is 13F°.. Industrial Research states, "The thermal discharge from a 1,000 megawatt power plant will affect 8 to 10 miles of an average-sized stream or about 5.5 square miles of a lake or bay." The discharged heated water speeds up the biological and chemical processes and changes the life cycles of fish. A change in the ecology of the area results eventually. The impact of thermal discharge is indicated by an estimate that our requirements for electric energy are doubling every 10 years.

Municipal water pollution problems comprise the interaction of various adverse factors. To list a few: less than a third of the nation is served by an adequate sewer system coupled with a waste treatment facility; about a third is served by inadequate facilities; the final third has no system at all. Municipal wastes are responsible for much of the nutrient pollution believed to result from phosphates. The cost to the public of solving the municipal waste problem has been estimated at $10 billion over the next 5 years.

Water pollution can be reduced by massive capital investment and by introducing innovative technology to solve various problems. Technologies that could play important roles in providing solutions are: dewatering of sludge; developing improved water quality monitoring systems; removing phosphates from waste; methods for eliminating thermal pollution; improved flowmeter systems; algae growth control; filtration processes; improved oil dispersion or removal methods; treatment of acid mine discharges; aircraft or satellite remote pollution/crop damage detection systems; osmosis filtration systems; and water and sludge recycling systems.

Air pollution, another long-time problem, has only recently been recognized as such. While water pollution frequently is visible, air pollution generally is more so. Public attention is drawn to the visible forms of air pollution: dark outpourings of industrial smokestacks, trails left by jet aircraft, and smog resulting from a combination of pollutants and meteorological conditions. But the total spectrum of air pollution is a complex of pollutants from many sources that are irritating and unpleasant, all damaging to some degree.

Photochemical and industrial smog cause damage to vegetation of a magnitude that is difficult to assess. In California's San Bernardino National Forest, two-thirds of the conifers totaling over a million trees, have been damaged by air pollution. In California alone, the economic damage to vegetation has been estimated from $8 to $132 million annually. The citrus crop has been reduced 50% by air pollution, primarily a result of ozone and photochemical oxidants from automobile exhaust. An estimated 50% of California's air pollution is attributable to this source.

Power and heat needs, primarily generated by burning coal, oil, or gas, are sources that are expected to increase air pollution. Resulting pollutants are sulfur dioxide, solid particulates including lead, nitrogen oxides, carbon monoxide, and hydrocarbons and their oxidation products. It is expected that the sulfur dioxide product will double between 1971 and 1990.

The hazards associated with air pollution cannot be overemphasized because of effects on health. A recent study of several types of cancer shows significant correlation of the disease with chronic exposure to sulfur dioxide and nitrogen dioxide. Based on this study, it is estimated that a fivefold reduction of Chicago's average annual sulfur dioxide concentration (with all other variables remaining constant) would reduce the city's cancer

deaths by about 800 per year. Health hazards are exemplified by several unfortunate air pollution catastrophes. One such occurrence in London in 1953 led to more than 4,000 "excess deaths." Another in Donora, Pennsylvania, in 1948 caused illness in more than 5,000 people and 17 "excess deaths."

Air pollution control and abatement are being advanced through the application of new technology. Problem areas requiring introduction of new technologies include development of: a new class of advanced pollutant sensors; aircraft and satellite remote sensory systems; control techniques for various pollutants; air pollution models; odor detection and control systems; and more efficient combustion processes. Also needed are new technologies for: analysis of effects of pollutants on human physical performance; reduction of motor vehicle exhaust; improvements in Rankine cycle engines and gas turbines; and improved particualte measurements.

Crime is a subject as topical as pollution as reflected by manifestly increased concern with law enforcement and the judicial processes. Crimes of violence that affect individuals personally account for much of the concern.Most aggravated assaults (about 67 percent of the total) are made by persons known to the victim. Aggravated assault statistics represent only one aspect of crime, but to the individual, it is a highly personal aspect.

A measure of the risk of sudden attack and injury made by persons unknown to the victim can be found in robbery statistics. Nearly half of all reported robberies take place on streets and about half of these are armed robberies. In one survey in the District of Columbia, it was found that some injury occurred in about 25 percent of such robberies. But the incidence of injury was found to be higher in unarmed robberies.

These statistics and others that could be developed indicate, according to the Commission on Law Enforcement and Administration of Justice, that ". . . on the average, the likelihood of a serious personal attack on any American in a given year is about 1 in 550; . . ." and further that the risk of attack by a stranger on the street is about half that of an attack by someone known to the victim.

Other forms of crime include employee theft and embezzlement, drug use, fraud, homicide, rape, and auto theft. The economic and social impact of crime is staggering and difficult to assess. The Commission reported that in 1965 it was estimated that there were 9,850 homicides, that half the 49,000 deaths in automobile accidents were attributable to negligent manslaughter or drunk driving, and that 290 women died from illegal abortion complications. The total economic loss in earning power was more than $1.5 billion calculated according to the time of death. The immense, overall loss to society is almost impossible to quantify.

Taking into account the above background, it is apparent that numerous areas in law enforcement, criminalistics, and the administration of justice would benefit from the application of technology. In fact, specific

recommendations made by the Commission reflect the need for technology in such areas as computerized command and control facilities; semiautomatic fingerprint systems; small, inexpensive portable radios for foot patrols; and an automatic car locator system. In other areas, there are needs for devices in criminalistic laboratories to assist in developing evidence; a means to locate objects underwater; better metal detectors; and improved accident investigation methods.

Transportation difficulties result essentially from mobility of the population, although there are other contributing factors. Disruptions of the population and the relocation of industry cause disruptions in the overall transportation system, particularly in urban areas. Public mass transportation problems occur. Freeway construction requires relocation of business and people. Many of those forced to relocate are those financially unable to do so. Lack of adequate public transportation leads to an increase in automobiles with a parallel increase in air pollution, traffic snarls, and accidents. This is emphasized when considering that since 1945, the number of automobiles in use has increased about 270 percent. Some $3 billion a year is being spent on urban highways. The number of buses in use has increased almost 50 percent, but service has apparently deteriorated and costs have spiraled. It appears obvious that the transportation sector could benefit from an infusion of technology.

Of the problem areas in transportation that need technological assistance, a partial listing is:

Systems planning of urban transportation needs
Investigation of human factors in automobile operation
Development of improved tunneling techniques
Development of improved aircraft noise suppression equipment
Improved passenger and baggage processing and handling systems
Investigation of crashworthiness of all types of vehicles
Development of better illumination for ground systems
Development of improved traffic network signal timing systems
Improvements in passenger restraints systems
Instrumentation systems for detecting rail stresses
Systems for detecting roller bearing failure on rail cars
Detection of illicit materials
Detection of clear air turbulence
Improved avionics.

Housing Construction and Rehabilitation is another important area of unmet human needs. It has been estimated that the more than 1,200,000 new housing units built each year merely keep pace with the demand caused by population growth, the demolition of old structures, and population mobility. New construction does not take care of the demand generated by replacement of substandard housing, with the result that those living in the substandard housing continus to do so. Efforts to alleviate the shortage of low-and medium price housing require a complex interaction of a number of agencies and individuals. Included are

the housing industry, which often is unwilling to invest capital in innovation that represents a risk; the unions, which are touchy about innovation which may change labor patterns or practices; the mortgage bankers, who are not venturesome in providing risk capital; the construction industry suppliers, who bear a high amount of risk in developing new products; and the consumer, whose taste in housing styles is not always consonant with more efficient and innovative construction techniques.

The typical construction firm is small and unable to support a research and development program. Little pressure is put on construction firms or the unions to develop and adopt new methods. Contractors continue to follow the basic methods of construction even though they now make use of power equipment in site preparation and lifting of materials, as well as using improved handtools. Special interest groups, outmoded zoning regulations and building codes, and fragmented local governments frustrate incentives for innovation.

There are a number of technologically related areas in which innovative developments could contribute greatly toward overcoming the obstacles to meeting housing requirements. These areas include:

A need for new methods to connect utilities in factory-built modular housing
Better techniques for rehabilitating buildings
Fire-extinguishing and fire-and smoke-detecting systems
Better exterior surface materials
Better fireproofing materials
More efficient electrical distribution systems
Improved sewage disposal systems
Better insulation materials to decrease heating costs
Improved, light-weight, and fire-resistant structural materials
Better nondestructive testing and joining techniques
Coatings, heat-resistant materials, and chemical additive for improved strength in structural steel
Improved spray foam application techniques
Research on fire-retardant foams.

Mine Safety is an area which is making use of technology and which requires improved technology but the subject has not been widely discussed in the past. Mine safety has achieved national attention only in the recent past and the public's concern for its importance fluctuates with the announcement in news headlines of mine accidents. A conspicuous example is the severity of the mine disaster at Mannington, West Virginia, in 1968 whose impact directed the attention of Congress and the public to neglected safety problems. While mine accidents involving multiple fatalities that blaze in new headlines capture the public's attention, most deaths occur in the daily routine and attract little attention. In 1966, according to statistics, 58 percent of the fatalities and 15 percent of the injuries sustained in the soft coal industry resulted from roof collapses. Effective ventilation of mines is necessary for safety, not only for breathing but also to prevent accumulations of highly explosive and

lethal methane gas. In addition to the necessity for proper ventilation, there are other problem areas: development of dust measuring instrumentation; unmanned vehicle technology; mine communications, borehole inspection devices; rescue and survival systems; breathing devices; rock stress indicators and detectors; explosion detectors; explosion quenching systems; and methane monitors.

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The following chapters present an overview of NASA technology, a description of NASA's Applications Team Program for technology transfer, and a summary of this program's achievements over the period from May through November of 1970.

# OVERVIEW OF NASA TECHNOLOGY

## OVERVIEW OF NASA TECHNOLOGY

With an overview of some of the problems which face our society, it is in order to illustrate currently available NASA technologies which may be applied in a positive manner to alleviate some of these problems. The aerospace research and development at the core of this new technology is not generally oriented towards providing a direct, short-term benefit to the man in the street. He will, however, continually benefit--both directly and indirectly--from the impact that this technology has had on industries such as computers, electronics, biomedical instrumentation, materials, and housing, to name only a few. A sampling of aerospace technologies that have had or will have an impact on some solutions to society's problems is presented below. These examples are representative of the vast scope and depth of technological knowledge, expertise and equipment which serves as the basic resource of the NASA Applications Team Program. The technology regularly used by the Program ranges from pieces of equipment or systems (hardware) to technical knowledge and expertise, computer programs, techniques, materials, and, often, highly creative ideas. The sources of this technology are NASA scientists and engineers, contractor personnel, and NASA-supported university researchers. A description of the NASA Applications Teams and the means by which they focus on these knowledge resources is described in the next chapter.

Bioinstrumentation. The conditions of spaceflight imposed uniquely stringent requirements on biological measurement systems. These requirements were met only through extensive cooperation between NASA medical and engineering personnel, and resulted in an entirely new order of bioinstrumentation technology. The main types of technological contributions were in the production of specific instruments and systems (usually for space flight), and in the formulation of systems requirements and specifications, and method for systems development and application. The key areas of bioinstrumentation system development are systems analysis, sensing, signal conditioning, power sources, telemetry, data processing and medical monitoring, prototype field test and evaluation in the field, and finally fabrication. Aerospace requirements focus equipment developments on noninvasive systems which do not frighten or traumatize the subject yet provide acceptable or improved physiological data. Such equipment is also highly desirable in the clinic, hospital, and health screening environment.

Systems analysis provides the methodology that establishes information requirements and equipment specifications for bioinstrumentation systems used on orbital and lunar human spaceflight. Because of its scope, its focus on critical medical problems, and its use of specially developed, advanced technology, this highly organized, goal-oriented planning approach offers valuable guidelines to the planner and user of bioinstrumentation systems for hospitals, remote physiological monitoring, clinical and physiological research, and similar nonspace situations.

The bioinstrumentation sensors, electrodes and sensor attachments include those elements that transform energy from one form to another such as the temperature-sensing thermistor, the spray-on electrode and other devices which make energy available for measurement such as integral electrode/buffer/ preamplification packages.

In a bioinstrumentation system, the signal conditioner operates between the primary sensor and the data transmission element. Signal conditioning is important because it determines the form of the biomedical information supplied to the system user. The form of data supplied directly influences the physician's concept and interpretation of the underlying physiological processes and thus his diagnostic capability. Three major examples that illustrate distinct facets of signal conditioner design that were developed by NASA and are applicable to non-aerospace programs are the Apollo electrocardiographic and Gemini blood pressure signal conditioners, and implant biotelemetry--recognized as a noninvasive means of obtaining continuous internal physiological data without encumbering the subject.

Efforts to accumulate biomedical information regarding man's ability to function in space has resulted in extensive revision of monitoring equipment and monitoring philosophy; sophisticated hardware and mathematical techniques represent advances in biomedical data processing and analysis. New measurement techniques now available for clinical and research use include impedance pneumography for respiratory measurements, and the development of the in-flight mass spectrometer which potentially brings a valuable laboratory analytical technique into the clinical environment.

Spaceflight bioinstrumentation fabrication incorporates a number of manufacturing and quality assurance techniques that are required to meet rigorous environmental stresses without sacrificing size, weight, power consumption or performance. Fabrication techniques developed for the space program have contributed to an improved state-of-the-art of clinical instrumentation in terms of size, quality, reliability and safety.

The many advances in bioinstrumentation technology resulting from aerospace research have contributed to the productivity of medical personnel; a productivity that often, up to this time, was hampered by the lack of available medical skills. The potential for automation and improved information that bioinstrumentation brings will not only supplement these scarce medical skills, but will also increase their productivity. Hopefully, it will result in cost savings and improved delivery of health care services to the ultimate consumer, the patient. NASA bioinstrumentation technology has already found application in the Automated Multiphasic Health Testing System which provides a rapid computer-generated summary of more than 40 medical measurements obtained during a half hour examination for some 25,000 patients annually at a cost of about $25 per patient. This is only one example of bioinstrumentation technology as applied in the private sector. The tremendous potential of current biomedical instrumentation is vast and has only begun to be tapped for the benefit of mankind.

Teleoperators and Human Augmentation. Man must work in outer space, ocean depths, and other hazardous environments, the exploration of which requires either assistance or substitution of man's extremities and thus his capabilities. Teleoperator technology provides an ability to augment man's hands, arms, and legs with machines. A teleoperator is a general purpose, dexterous mechanical substitute for man's limbs. This man-machine cooperation enables man to pick up and examine samples of the lunar surface while remaining on earth, to repair an underwater oil pipeline from the surface of the ship, to manipulate radioactive nuclear fuel elements in a "hot" atomic cell, or to lift a ton-sized load --- the man amplifier concept. Three considerations help determine when a teleoperator system will be used: man's absolute physical limitations in matters of strength, size, and bodily construction; the need for human welfare or safety; and economic considerations. An astronaut is vulnerable, expensive, and non-expendable, thus special purpose remote-control machines have been developed by NASA to perform many manipulative tasks in outer space.

Secondary application of these remote-control machines and of teleoperator technology generally is now successfully being accomplished in the prosthetics (artificial limbs) field as engineers apply improved materials, better power supplies, and improved control techniques. In the future, the augmentation and extension of man by teleoperator will enable man to conquer factors of distance, high temperature, high pressures, noxious atmospheres, and other dangerous environments on the periphery of his narrow domain. For example, it may permit a surgeon to perform surgery on a patient a thousand miles away or it may help marine scientists to mine and cultivate raw material and food supplies now locked deep in the oceans.

Digital Image Enhancement. Digital computers have been widely used in the aerospace community to correct various photometric, geometric, and frequency response distortions in the images received from the television cameras of Ranger, Mariner, and Surveyor spacecraft. Two types of processing can be performed by a digital computer on a television image. The first type of processing is content analysis by which the computer extracts information from the image and presents the resultant information non-pictorially, that is, as numerical data. In the second type of processing, image enhancement, the goal is to improve an image so that a human photo-interpreter can more readily find what he is looking for. This image enhancement or two-dimensional digital filtering is particularly useful for bringing out fine detail that is often invisible in an unprocessed image. This computerized image enhancement method has proven invaluable in revealing detail that was not previously obtainable in medical and biological photographs. Subsequently, it is being applied to facilitate the interpretation of chest x-rays and retinal images, besides being used in light microscopy image enhancement of chromosomes. A closely related application has also occurred in which an optical tracking device has been applied to studying blood flow velocity in the capillary blood vessels, research important to an improved understanding of the body's ability to react to or withstand severe environmental stresses.

Clean Room Techniques. Clean room techniques are used to prevent entire space missions from failure because of contamination of spacecraft components. Strict contaminant control is imperative; for example, the function of a propellant system valve in an altitude control device could be impaired by very small particles of contamination. This could result in loss of spacecraft, lives and large economic investments. Two design concepts for clean rooms are in current use--an older type referred to as a conventional flow clear room and a more advanced design using the laminar flow principle. Interest in incorporating this laminar airflow principle into hospital construction has been widely expressed. Requests come from organizations such as the Washington University Department of Cardiothoracic Surgery. This organization has also requested information on such space-derived techniques as sterilized filtration, positive pressure environments, and contamination-free clothing. The anticipated benefit from the adoption of aerospace clean room techniques is the marked improvement in contaminant control and therefore, the prevention of infections in surgical operating rooms.

Satellites in Communication, Weather Forecasting, Geography, Cartography, and Agriculture. Satellites have been one of NASA's primary contributions to the improvement of communication, weather forecasting, geography, and agriculture. The application of satellites to such disciplines resulted from extensive scientific and engineering investigations conducted during preparation for the manned Gemini and later the Apollo Programs.

The communication satellite, which is used for international television, orbits thousands of miles above the earth in order to afford a living room view of such events as the Olympics in Mexico and France, the induction of the Prince of Wales, and the opening of Expo '70 in Japan. Although enjoying widest renown, television is not the primary benefit of the communication satellite. Far more significant gain has come to world commerce through the satellite's ability to provide cheaper and more reliable, long-range communications, and through the ease of contact it provides by virtue of its capacity.

The meteorological satellite has brought many technological, economic and social returns through the technique of weather forecasting by space observation. The satellite, which employs sensors that sense such atmospheric conditions as temperature, pressure, moisture, and air movement, is widely used to identify destructive storms. The disciplines of geography, land use and cartography are aided by data derived from orbital sensors which observe the direction of urban development trends, the interpretation of trends in crops, and land use. NASA's continued commitment to an Earth Resources Technology Satellite (ERTS) Program will continue to expand and improve the value of remote sensing technology and its solid economic value.

Environmental Monitoring Technology. A spacecraft cabin is a closed ecological system, thus it is a requisite for manned spaceflight that a nontoxic environment be maintained within the cabin. A great deal of effort was expended by NASA in identifying, measuring, and controlling the atmospheric components of the sealed-spacecraft-cabin atmosphere. Much of this effort has resulted in the design and production of monitoring equipment, equipment that has been found to be functionally suited to air pollution monitoring on a broader scale.

Developments in monitoring devices that represent unique and improved features applicable to air pollution monitoring include, for example, a mass spectrometer that can continuously monitor the respiration of a test pilot for correlation of quantities of various respiration products with stress conditions being experienced by the pilot. This compact instrument, which has an exclusive vacuum system and a high reliability rating has, in its present form, been found suitable for use as an air pollution monitor for gases within the 3- to 100-atomic mass unit range, and can meet current monitoring activities without much additional developmental costs. An instrument built to the specification of this prototype is suitable for detection and analysis of the gaseous constituents of the atmosphere and a slightly modified instrument that is mobile would be suited for use by civilian monitoring agencies.

Another piece of technology is the trace-gas analysis procedure developed to collect and analyze gases in the Apollo spacecraft cabin. It is suitable for use in air pollution research facilities to monitor special manufacturing processes, or in research work. A third item is a device used to detect glycol vapor in spacecraft cabin atmospheres. The device is suitable for detection and analysis of glycol in the atmosphere at a very low per-sample cost.

Other instruments and techniques usable for air pollution monitoring activities include a hot-wire detector for chemically active materials once used for cabin-contaminant identification and analysis, and a microwave spectroscope in which detection of molecules is based on the absorption of various microwave wavelengths by different gases.

The identification and analysis of possible toxic concentrations of gases and vapors within a spacecraft cabin are not the only areas of gas monitoring, in which NASA has contributed technology. Other aerospace-developed analytical systems include welding gas monitors, welding spectrometer analyzers, and clean assembly-area monitors. As in the case of cabin-atmosphere monitoring, these techniques, too, have applicability to the monitoring of air pollutants. Finally, measurement of air pollution from satellites is now also feasible through use of such instruments as lasers, infrared sensors, and microwave equipment and will provide information that will contribute to the detection of contaminants which threaten our environment.

Microelectronics, Integrated Circuitry and Third Generation Computers. NASA space research programs have been most active in the development and application of microelectronic devices. These devices encompass technologies by which electronic circuit functions are fabricated in small, solid structures that are both reliable and inexpensive. Microelectronics, invaluable in such applications as the IMP I satellite's optical aspect computer, the test apparatus that provides ground support equipment for the Apollo guidance computer, and the circuitry of multichannel digital computers, are now finding widespread commercial application in telephone switching circuits, television, and small desk-type and other commercial computers. Microelectronic technology is expected to open entirely new possibilities in electronic instrumentation and data processing in which it will be used to implement many new applications which otherwise would not be feasible or which would be done less efficiently.

The requirement to check out and determine flight status of the major components of the booster stages and vehicles, hundreds of subsystems, thousands of assemblies and hundreds of thousands of individual devices, stimulated the development of completely new and unique methods. As the time factor required for checkout to meet the very narrow launch constraints is critical, automated methods were essential. To use automatic or computer operated test methods, NASA, early in its program, required the computer industry to develop machines with greatly expanded memory capacity and significantly faster computational ability. These requirements made the drum memory unit obsolete and forced the redesign of electronic circuitry. The so-called "Third Generation Computer" was born with its massive banks of disk and core memories and introduced integrated circuitry into computer design. This new machine probably best identified by the trade name "IBM 360 System" is the system that is revolutionizing accounting, record keeping, banking, technical data banks and data processing, and has fostered a new industry identified as "Time Sharing". This is the system where a number of companies with associated requirements for data processing share a computer by using remote consoles, rather than maintaining a computer installation in their facility. The "Time Sharing" concept has made modern computer technology available to medium size and small businesses, thereby improving profit potential and competitive position in the market place without their having to make large capital investments in computer equipment.

Fuel Cell Technology. Unmanned vehicles secure their power from the sun through solar cell arrays which provide adequately for their low power usage. The Apollo Program required much higher power levels to power the Command Module. Sky Lab, a space orbiting scientific workshop, will require still higher power levels for operation of the many scientific experiments as well as providing for life support systems for the men living in the orbiting lab for up to 30 days. This power requirement has led to the consideration and development of small isotope or atomic power generation plants. Although these components present safety hazards when an integral part of a space station, shielding methods and materials are being developed to meet this need. Development of the small atomic generator or fuel cell may lead to each home and building having its own self-contained power supply and reduce dependence on the rapidly disappearing supply of fossil fuels. It is interesting to note that the fuel cell delivers a bonus in a supply of fresh clean water. This might make a new supply of water available to every home, thereby reducing our demands on presently available natural supplies, allowing our ecologists needed time to institute anti-pollution programs to restore the ecological balance in lakes, rivers, and streams.

Inorganic Coatings. Advanced space/missile requirements dictate the development of new combinations of materials with markedly superior properties. The sophisticated combination of two or more substances into a composite-materials system yields a combination of properties unobtainable from either substance. An example is a vitreous-porcelain enamel which combines the strength, flexibility, and other useful properties of the metallic substrate with excellent chemical resistance, diversity of color and texture, and ease of cleaning. Inorganic coatings represent an important division of composite-

materials systems currently undergoing rapid development to serve novel applications, and comprise materials such as glasses, crystalline ceramics, carbides, silicides, borides, sulfides, and metals. These coatings have application in areas such as thermophototropic coatings which assure new optical devices with optical properties that respond to light intensity, and thermal control coatings useful for solar energy conversion systems and thermal control. A practical example of recent application of NASA-developed inorganic silicate paint is the use of such paint by a university research center to coat the interior of a steel high pressure oxygen chamber to supply a hard, inert coating that will not, as has occurred with previous coatings, permit contamination through chamber deterioration to the high oxygen, high moisture atmosphere.

Portable Life Support Systems. The challenges of the lunar environment, as well as extravehicular activity, required pressure maintenance and oxygen supply for the astronauts. Space program research in intra- and extra-vehicular operations has advanced technology in the following areas: oxygen supply and pressurization, carbon dioxide contaminant control, thermal and humidity control, power, communications--voice and telemetry channel, and instrumentation controls and status displays. Subsequent development of life support systems include the Portable Environmental Control System (PECS), the NASA aircrew oxygen system, fluidic temperature control for liquid-cooled space suits, techniques for excess metabolic heat rejection from the outside surfaces of protective suits, a heat rejection system for the extra-vehicular astronaut, solid oxygen for portable life support, research on sodium chlorate candles for the storage technology from these systems can and will contribute to improved life support systems for use by miners and firemen.

Composite Materials. Composites are materials possessing high strength-to-weight ratios. The most fundamental of these probably are the fiberglass laminates, which we all recognize as used in power boat hulls and automobile bodies. Advanced NASA requirements are developing entirely new types of composite materials where thousands of whiskers or small needles of carbides are combined with aluminum and other metals during the smelting process, culminating in alloys for castings and forgings with greatly improved physical properties. Composites emerging from this research will provide the industrial designer with new materials which will allow for greater innovation and flexibility in product applications. Other forms of filament composites, originally used in the fabrication of missile bodies and rocket engine nozzles, are being used in the fabrication of housing modules for innovative urban development projects.

Solid Lubricants. Improved lubricating materials are constantly being sought in an effort to further reduce the energy loss and component wear caused by friction. With increasing trends toward the use of higher and higher temperatures in moving parts, commonly used petroleum oils quickly became inadequate and have had to be replaced by new, synthetic materials. With the introduction of supersonic aircraft and spacecraft, temperature and pressure conditions became even more severe and the search for more effective lubrication resulted in the development of solid lubricants. Solid lubricants have the advantage of good stability at extreme temperatures and in chemically reactive environments and

afford the design advantage of lighter weight, simplification, and improved dynamic and mechanical stability; a must in modern aviation and space technology. Solid lubricants show a large market potential for use in the automotive, heavy electrical, metal working, and marine industries. Although solid lubricants will not totally replace the more conventional lubricant, they will open up new frontiers to operating machinery, not only under high temperatures, but also under conditions of extreme cold, very high vacuum, nuclear radiation, and extreme loads.

Systems Management. NASA-supported projects have been so large and complex that the systems approach to their management was not only desirable but necessary. Systems analysis technology can be illustrated as a spectrum of techniques related to each other by several common characteristics which describe the approach taken to problem solving -- specifically, a systematic and usually quantitative approach which concentrates on the system as a whole, as opposed to its constituent elements. Techniques which comprise this new technology include, among others, operations research, operations analysis, cost-benefit analysis and engineering-economic analysis. Since the common characteristics of systems technology focus on the type of approach to problems involved, this systems management approach can be used to attack large classes of problems in many disparate areas. The value of this approach is aptly illustrated by the use of systems analysis in the planning of a $100 million hospital complex in Alberta, Canada, in which officials estimated that the study saved $6 million in brick and mortar costs alone, and it was anticipated that increased staff efficiency by virtue of optimum design would save another $12 to $14 million.

Related to systems management concepts is the concept of integrated management information centers. These centers, such as the one at Kennedy Space Flight Center, use a variety of data display techniques and capabilities to provide a particular project management group with a unique management device. These centers provide access to and display all information relevant to a project management decision-maker's task. The concept has been adopted for use by city personnel involved in the construction of a new airport and in the management of other public works construction projects.

NASA'S RESPONSE TO THE NEED FOR
TECHNOLOGY: AN ACTIVE PROGRAM
FOR TECHNOLOGY TRANSFER

## NASA'S RESPONSE TO THE NEED FOR TECHNOLOGY:

## AN ACTIVE PROGRAM FOR TECHNOLOGY TRANSFER

The National Aeronautics and Space Administration has generated a vast amount of scientific and technological knowledge in a great variety of disciplines and fields. Cognizance of the need to maximize the utilization of this knowledge led the Congress, as stipulated in the original Space Act of 1958, to call for ". . . long-range studies of the potential benefits to be gained from, and the problems involved in, the utilization of aeronautical and space activities for peaceful and scientific purposes." The Congress charged NASA specifically with the obligation to ". . . provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

### OBJECTIVES OF THE TECHNOLOGY UTILIZATION PROGRAM

To assist in carrying out that obligation the NASA Technology Utilization Program was initiated in 1962. The stated objectives of NASA's Technology Utilization Program are:

> To increase the return of the national investment in aerospace research and development by encouraging additional uses of the knowledge gained in those programs
>
> To shorten the time gap between the discovery of new knowledge and its effective use in the marketplace
>
> To aid the movement of new knowledge across industry, disciplinary, and regional boundaries
>
> To contribute to the knowledge of better means of transferring new knowledge from its points of origin to its points of potential use.

In order to achieve the objectives set forth, a two-pronged approach to the problem of technology transfer was established. The Scientific and Technical Information Office was formed to acquire, publish, and disseminate aerospace information and was charged with the responsibility to work according to, as well as to improve, the traditional information dissemination mode. In addition, the Technology Utilization Office was formed to institute new approaches to all of the facets of the technology transfer process, namely the identification, evaluation, publication and dissemination functions of an active technology transfer program.

## THE TECHNOLOGY UTILIZATION OFFICE

The Technology Utilization Office's approach for increasing the uses of aerospace technology, for purposes other than aerospace, has been a series of experimental programs. These programs were designed to explore various approaches toward rapid and effective communication of new knowledge to different potential users. The various programs now sponsored by the Office are conducted in technology identification, acquisition, and evaluation phases and the technology application phase.

Most of the technology utilization research effort in the input phase has been directed toward improved methods of identifying and acquiring new technology from the research and development efforts of NASA scientists and contractors. The program provides for a Technology Utilization Officer at each NASA research installation throughout the country. The Officer has the responsibility of ensuring that the scientific personnel at the installation, as well as those of contractors connected with that installation, document and report (separately from their technical reports) any inventions, improvements, or other forms of new technology developed.

A number of experimental programs are also underway in the output phase, with continuing emphasis on communication with, rather than dissemination to, the potential user. A means of communicating with the user, ongoing since 1963, has been the NASA Tech Brief program. A concise one- or two-page announcement, the Tech Brief describes in general terms the availability of new NASA Technology, and includes references to those places were additional, more detailed information may be obtained. The Tech Briefs are distributed to personnel in industrial, governmental, and educational organizations so that they know of new NASA technology and are able to communicate with appropriate NASA personnel to learn more about it.

The acceleration of Technology flow from developer to user required an intermediary party or "coupler" to coordinate communication between the technology source and receptor. The Regional Dissemination Center (RDC) program utilizes this "coupler" concept. It is a network of university-based and geographically dispersed computerized information storage and retrieval centers (RDC) and technological information from the Scientific and Technical Information Office is supplied to them in the form of computer tapes. Qualified RDC personnel acting as "couplers" search the computer tapes for appropriate aerospace technology in response to specific requests and provide a specialized package of information applicable to the problem of the requester.

The Applications Team Program is another interesting and successful experiment instituted by the NASA Technology Utilization Office to accelerate the transfer of aerospace technology to the non-aerospace user through the use of the "coupler" mechanism. This report focuses on the recent achievements of the Applications Team Program.

## THE APPLICATIONS TEAM PROGRAM

NASA was aware of many efforts at implementing concepts of technology utilization which were passive in nature, that is, information (or technology) is provided to those who are able to seek it. The Applications Team Program pursues an active rather than passive effort, and carries the "coupler" concept one step further. Both problems and solutions are actively sought by the coupler mechanism, in this case, the Applications Team.

The Applications Team experiment, as originally conceived in 1965, was intended to involve a core of Technology Applications Teams located at various research institutes and staffed by professionals from a variety of disciplines. These teams were to meet with investigators to define their problems and to try to locate potential solutions by searching the NASA information system. The teams would, therefore, provide an interface between a problem from one research area and a potential solution from a quite different research area. The research area studied initially was biomedicine and the original Biomedical Applications Team experiment tested and verified these hypotheses:

- Biomedical researchers are receptive to new technology and would adapt it if it were available and within their resources

- The flow of aerospace technology to applications in biomedicine can be accelerated

- A multidisciplinary interface between the NASA aerospace data bank and biomedicine, using a systematic experimental methodology to identify and relate technical needs with potentially applicable aerospace technology, offers an effective means for translating this singularly oriented mission information to a new mission area such as biomedicine.

The initial success of the Biomedical Applications Team and increased public interest in potential use of aerospace technology to solve other pressing social problems led to an expansion of the Application Team Program. The Program now focuses on such public problem areas as air pollution, water pollution, criminalistics and law enforcement, urban construction, transportation, and mine safety.

The Biomedical Applications Teams currently have 56 institutions actively participating in the program, which are listed in Table 1. The public sector Technology Applications Teams have 53 actively participating institutions as listed in Table 2. A significant achievement and advantage of the Applications Team concept is that it gained widespread acceptance in professional communities which are often described as being reluctant to accept and utilize new technology. The relatively short history of the NASA Applications Teams has clearly demonstrated that traditional communications barriers can indeed be bridged when there are well focused and directed efforts made to solve pressing problems of our society.

## TABLE 1

## INSTITUTIONS CURRENTLY PARTICIPATING IN THE BIOMEDICAL APPLICATIONS PROGRAM

Albuquerque Veterans Administration Hospital
Baylor University College of Medicine
Bay Pines Veterans Administration Hospital
Birmingham Veterans Administration Hospital
Bowman Gray School of Medicine Wake Forest
Children's Hospital of Los Angeles
Creighton University School of Medicine
Dallas Veterans Administration Hospital
Doheny Eye Foundation, Los Angeles
Duke University
Gainesville Veterans Administration Hospital
Gallup Indian Medical Center
Hollywood Presbyterian Hospital, Los Angeles
Hot Springs Rehabilitation Center
Institute for Rehabilitation Medicine
Jackson Veterans Administration Hospital
Loma Linda University Medical School
Long Beach Veterans Administration Hospital
Los Angeles County/USC Medical School
Louisiana State University
Milwaukee County General Hospital
National Cancer Institute
National Environmental Health Sciences Center
National Heart and Lung Institute
National Institute for Neurological Diseases and Stroke
North Carolina Division of Vocational Rehabilitation
North Carolina State University
Ochsner Foundation and Clinic
Oklahoma Veterans Administration Hospital
Parsons State Hospital and Training Center
Rancho Los Amigos Hospital
Scott White Clinic
Sepulveda Veterans Administration Hospital
St. Joseph's Hospital
St. Luke's Hospital
Texas A & M University, College Station, Texas
Tulane University
UCLA College of Medicine -- Orthopedics
United Cerebral Palsy Association
University of Alabama Medical School
University of Arizona College of Medicine
University of California at Davis
University of Florida College of Medicine
University of Iowa School of Medicine
University of Kansas, Medical Center
University of Minnesota

TABLE 1 (con't)

University of Missouri
University of Missouri Dental School
University of North Carolina
University of North Carolina Dental School
University of Southern California Medical School
University of Texas Medical Branch at Galveston
University of Texas Medical School at San Antonio
University of Texas Southwestern Medical School
University of Utah Medical School
University of Washington
University of Wisconsin
Veterans Administration Southern Research Support Center
Veterans Administration Western Research Support Center
Washington University
Western Missouri Mental Hospital
Woodrow Wilson Rehabilitation Center

## TABLE 2

## INSTITUTIONS CURRENTLY PARTICIPATING IN THE TECHNOLOGY APPLICATIONS PROGRAM

### Air Pollution

Air Resources Board, California Department of Public Health
Bay Area Pollution Control District
California Department of Agriculture
California Statewide Air Pollution Research Center
Los Angeles County Air Pollution Control District
National Air Pollution Control Administration
State of Washington Air Pollution Control Board
Utah State Division of Health

### Water Pollution

Chicago Metropolitan Sanitary District
City of Dallas, Texas
Federal Water Quality Administration Laboratories

### Law Enforcement and Criminalistics

California State Bureau of Criminal Identification & Investigation
Chicago Fire Department
Chicago Police Department
Cleveland Police Department
Contra Costa County Sheriff's Office
Los Angeles Police Department
Maryland State Police
New York City Fire Department
New York City Police Department
Oakland Police Department
Port Authority Police, New York
San Francisco Police Department
San Mateo County Sheriff's Office
Santa Clara County Laboratory of Criminalistics
Seattle Police Department Criminalistics Laboratory
U.S. Postal Service

### Mine Safety

U.S. Bureau of Mines Research Laboratories

TABLE 2 (Con't)

Transportation

Bay Area Rapid Transit District
California Division of Highways
California Highway Patrol
Center for Urban Regionalism
Department of Highways, State of Pennsylvania
Department of Highways, State of Washington
Fairbanks Highway Research Station (DOT)
Federal Highway Administration (DOT)
Federal Railroad Administration (DOT)
Highway Research Board
Highway Safety Research Center, Chapel Hill, N.C.
Highway Safety Research Institute, Ann Arbor, Michigan
Montana State Highway Commission
San Jose (California) Traffic Engineering Department
Southern California Rapid Transit District
Urban Mass Transit Administration (DOT)

Urban Development

Department of Housing and Urban Development
Urban Development Corporation of the State of New York
Branson Sonic Power
Burndy Corporation
Civil Engineering Program Applications (21 active clients for computer software)
Hauserman
Owens Corning
Reichhold Chemical
Stanley Works

The objectives of the NASA Applications Teams are:

> To identify significant public problems and needs existing in the problem areas studied which appear to be "solvable" by application of aerospace technology
>
> To seek out and identify specific aerospace technologies or concepts which may lead to solution of these problems
>
> To advise or guide problem originators, as appropriate, in the application of these techniques to their problems
>
> To document successful application of aerospace related technology by researchers as a result of their participation in the Applications Team Program.

A key characteristic of the Applications Team Program, as noted previously, is that by definition it is participative. Participation or involvement is considered essential to successfully gain user acceptance and transfer technology from one discipline to another. One Biomedical Applications Team director noted:

> "Personnal interaction is vital when two diverse disciplines are attempting to interact. In fact, disciplines do not interact, but people do. The interaction between two diverse disciplines really results when two people sit down to talk. If we simply give a physician an engineering document, the results are usually zero. The physician cannot begin to realize the significance of modern communications technology to his method of dispensing health care, and the engineer cannot recognize the significance of his cryogenic technology to leukemia therapy until face-to-face and repeated personal interaction occurs. Personal interaction between all elements of the team program (physician, team member, and aerospace engineer) has been found to be of major importance for success."

The brief description of Applications Team Methodology which follows underscores the continuous involvement of the researcher with a problem in every phase of the team effort.

## METHODOLOTY

The Applications Team Program, as an experimental effort, requires constant review and modification of program methodology in order to take advantage of knowledge gained. The four general phases of the program's methodology have, however, remained essentially unchanged. They are: problem identification, definition and acceptance; search for applicable aerospace technology; evaluation and application of the technology; and transfer documentation.

Problem Identification, Definition, and Acceptance. Introduction to the Applications Team Program is made through a formal presentation delivered by a team member. However, informal discussions with colleagues already

participating in the program may interest the non-participant. The prospective Problem Originator then arranges a conference with an Applications Team member, where the technological problems of the prospective Problem Originator are discussed in detail. In the next step, the team member defines the problems in concise terminology of the physical sciences and conducts a preliminary evaluation of each proposed problem.

The preliminary evaluation includes a review of team in-house technology files to serve as pertinent background information. The technology files are composed of commerical product data, NASA publications, historical data on previously accepted problems, potential transfers, and transfers. After the background information is reviewed, each proposed problem is screened against broad acceptance criteria. These criteria vary somewhat among the Applications Teams, but generally, the factors considered are:

VALUE - Solution to the problem should significantly contribute to progress towards overcoming a major problem identified by the profession served

SPECIFICITY - The problem should be sufficiently discrete to facilitate formation of specific search strategy

SOLVABILITY - The problem should appear reasonably amenable to solution by aerospace technology or expertise

A proposed problem would rarely be accepted for study if it appeared readily solvable, either by known commerically available technology or by knowledge gained from a similar problem, previously solved through Technology Applications Team Program efforts. In both cases, the proposed problem would be rejected and the prospective Problem Originator informed of the available technology. (The Problem Originator is always informed of the reasoning behind rejection of his proposed problem.)

When a problem is formally accepted, the team member prepares a Preliminary Problem Statement which summarizes what is known of the problem at the time, and serves as a means of "gathering thoughts" on the problem prior to search initiation.

Search for Appropriate Aerospace Technology. A preliminary search is based on the initial definition of the accepted problem, augmented by assistance from qualified search personnel at the Regional Dissemination Center (RDC) that supports the designated team. A team member then constructs a comprehensive search strategy and the vast NASA Aerospace Data Bank is searched for appropriate technology.

The problem of retrieving relevant documents for a non-aerospace user is difficult. To accomplish this task one must devise a computer search strategy which will pair subject groups. If only one subject group were used the computer would retrieve more documents than could be economically screened and processed. Use of a second grouping eleminates many of the extraneous documents. For

example, if the problem involved blood flow rate measurement, the search strategy would be constructed to locate all information on technology developed by NASA to measure the blood flow rate and other physiological parameters of astronauts in outer space. The broad groupings used might be medical; sound; flow; and signal analysis.

Pairing of the groups as discussed above will not always recover all relevant documents in the data bank. Many documents will be indexed only under one of the groups. But these documents may be indexed under an aerospace term describing the aerospace problem or objective for which the technology was developed. It then becomes necessary for the strategy designer to determine what these aerospace problems or objectives were. Using the blood flow rate measurement as an example again, it would be necessary to develop the search strategy to recover aerospace related information indexed under aerospace terms. For example, technology developed to measure liquid fuel flow rate through flexible tubing in spacecraft might be applicable. Recovery of documents related to this aerospace problem would enable the search strategist to determine the keywords used in indexing that document. These keywords could then be used in further developing the search for aerospace technology relevant to the non-aerospace problem. The end product would be aerospace technology developed to solve a problem quite different from the blood flow rate measurement problem but yet broadly related in a technical engineering sense.

Searching for aerospace technology also involves another means, that of the active participation of NASA scientists and engineers. To obtain such participation, the team member prepares a formal Problem Statement which includes a definition and detailed description of the problem, inadequacies of currently available technology, constraints and restrictions on potential solutions, and impact of potential solution. The Problem Statement is prepared in non-disciplinary technical terminology, and reviewed by the Technology Utilization Office prior to dissemination by the NASA Technology Utilization Officers at the NASA field centers, who in turn distribute them to appropriate participating NASA scientific and technical personnel.

NASA personnel, having reviewed the Problem Statement, may be aware of a potential solution. They respond by contacting the Applications Team member through the installation's Technology Utilization Officer. A description of the potential solution is forwarded to the Team through the Technology Utilization Officer.

The Aerospace Data Bank search and the Problem Statement distribution provide for identification of most of the reported and unreported NASA technology. Thus, these are the most widely used methods of teams searching for particular technology. Other means of accessing information on NASA technology are being explored by the teams, such as visits to NASA field centers, and conferences between Problem Originators and NASA scientific personnel.

Evaluation and Application of the Technology. The Applications Team member evaluates the information on available aerospace technology after receiving the results of the RDC computer search, responses to Problem Statements

or any other pertinent information from other sources. He makes a preliminary determination as to whether the identified technology might provide a solution to the problem under study. The extent of this team member evaluation varies from team to team, depending on the particular problem under study, the team member's relationship with the Problem Originator as well as his needs and objectives.

RDC search results are processed by sending abstracts of technical documents considered applicable to the team member; he reviews the abstracts, marking those that seem relevant to the problem. These are transmitted to the Problem Originator for evaluation. The same procedure is followed for evaluation of responses to Problem Statements. The team member rarely fails to identify at least some applicable technology in the computer search results or the Problem Statement responses. Irrelevant information, as a rule, is not passed along to the Problem Originator. Instead, the team member re-evaluates the problem. The reevaluation forms the basis for redefining the search criteria or for closing out the problem.

When the Problem Originator receives the results of the team search activities, he also evaluates the information. If his evaluation indicates no potential apparent solutions, the Problem Originator notifies the team member, and a second evaluation of the problem is made.

If a potential solution to the problem is found, the problem is then known as a Potential Transfer. During the time between Potential Transfer and Transfer, the team member and the Problem Originator work together closely to bring the Transfer to fruition. This involved interaction includes such activities as locating NASA hardware for loan and/or development of design specifications for fabrication, obtaining funding or other means to modify or fabricate, and arranging for test experiments. These steps cause the time required to bring a Potential Transfer to the Transfer stage to vary considerably, depending on the problem.

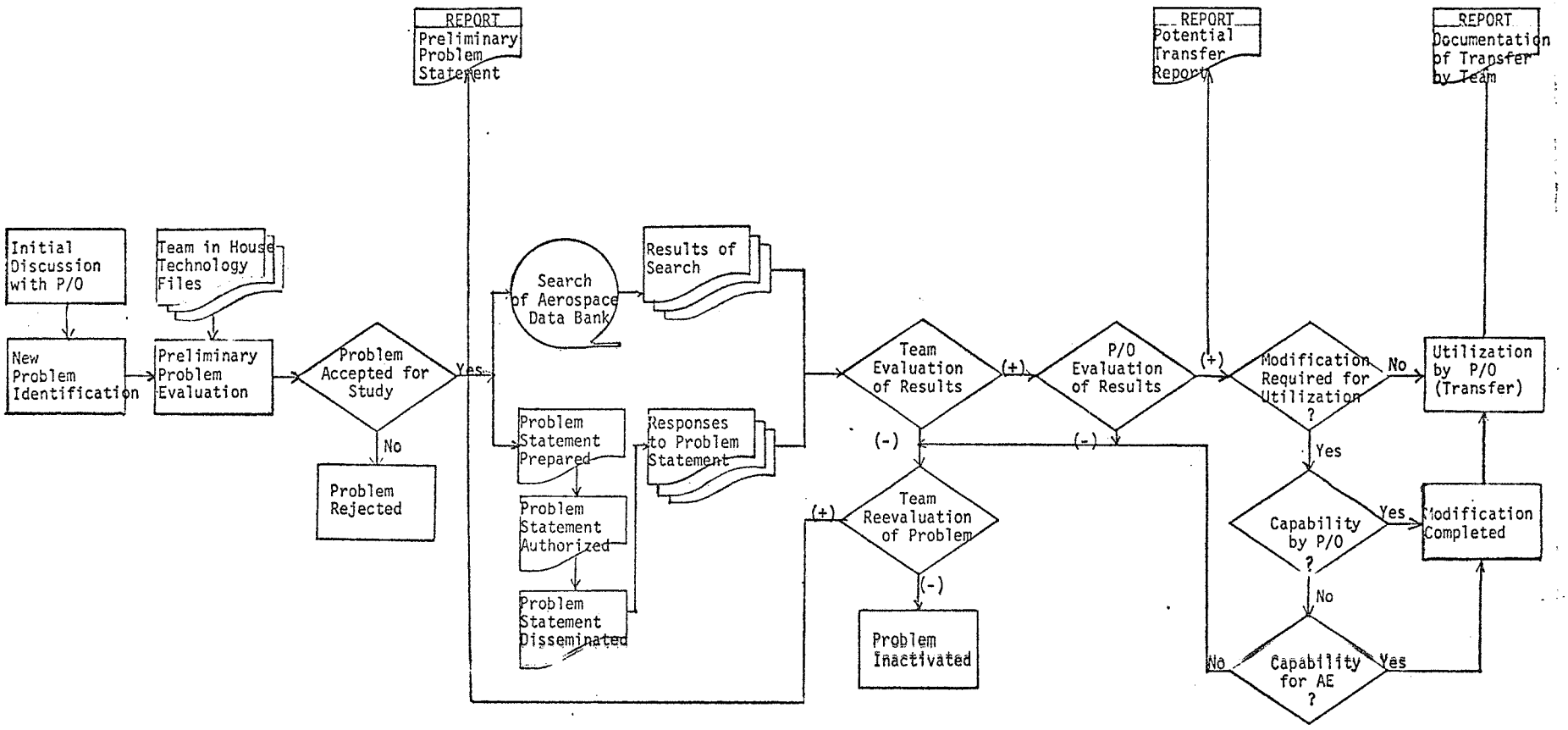
Transfer Documentation. The team member has the responsibility of preparing a Transfer Report after fabrication and testing, and successful application of the technology to the problem. This completely documents both the process and impact of successful transfer of aerospace technology. A flow chart of the basic applications team methodology is shown in Figure 1.

## CURRENT PROGRAM ELEMENTS

There are seven NASA-funded Applications Teams currently in the program. Three are the original Biomedical Applications Teams (BAT), located at Midwest Research Institute (MRI), Research Triangle Institute (RTI), and Southwest Research Institute (SwRI). A fourth Biomedical Team is currently being established at Stanford Medical School.

Three other Applications Teams also located at research institutes are designated Technology Applications Teams (TAT), since they function to study public sector problems other than biomedical. Their locations are: IIT Research Institute (IITRI), Research Triangle Institute (RTI), and Stanford Research Institute (SRI).

FIGURE 1. FLOW CHART OF BASIC APPLICATIONS TEAM METHODOLOGY




(+) Favorable Evaluation
(-) Unfavorable Evaluation

P/O Problem Originator
AE Applications Engineering

FIGURE 2. GEOGRAPHIC DISTRIBUTION OF NASA APPLICATIONS TEAMS

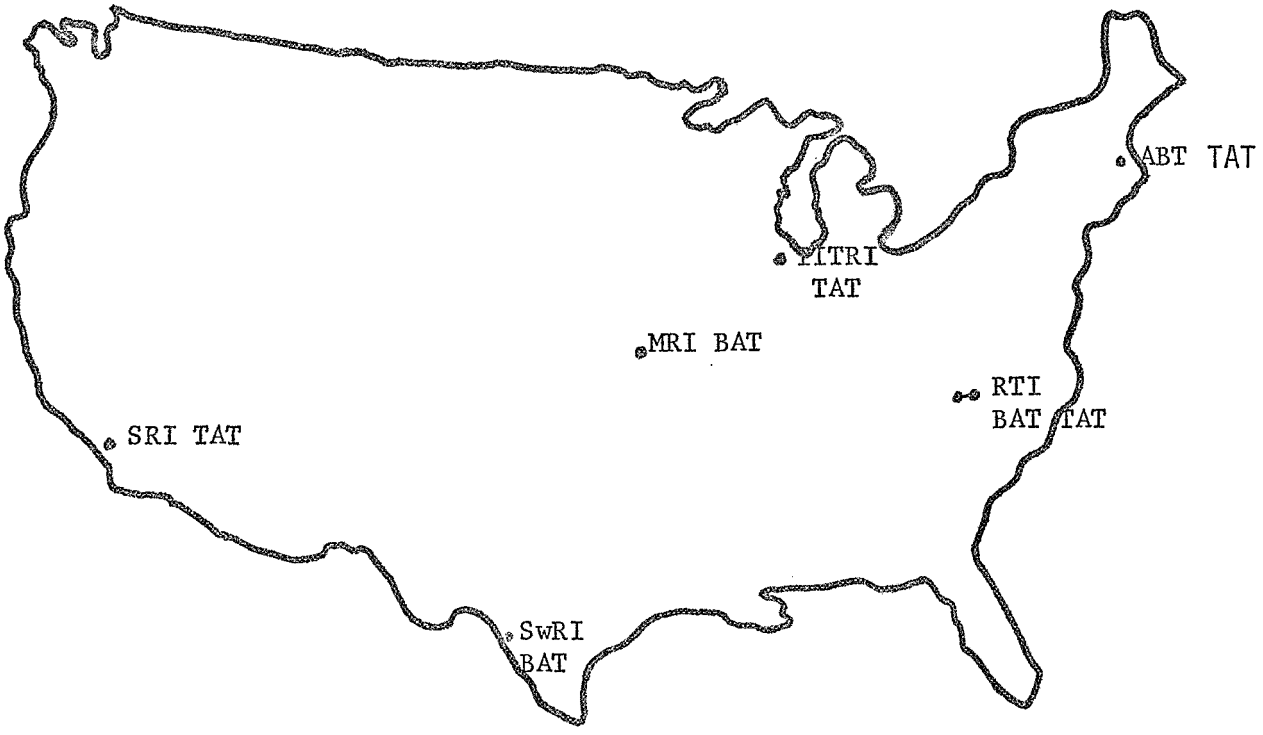


TABLE 3

PROBLEM AREAS STUDIED BY NASA APPLICATIONS TEAMS

| TEAM LOCATION | PROBLEM AREAS |
|---|---|
| IIT Research Institute<br>Chicago, Illinois | Law Enforcement<br>Mine Safety<br>Water Pollution |
| Midwest Research Institute<br>Kansas City, Missouri | Biomedicine |
| Research Triangle Institute<br>Research Triangle Park, North Carolina | Air Pollution<br>Biomedicine |
| Southwest Research Institute<br>San Antonio, Texas | Biomedicine |
| Stanford Research Institute<br>Palo Alto, California | Air Pollution<br>Criminalistics<br>Transportation |
| ABT Associates, Inc.<br>Cambridge, Massachusetts | Urban Construction<br>and Planning |

A fourth Technology Applications Team has been instituted recently at ABT Associates, Inc., an interdisciplinary research and consulting firm oriented toward urban problem solving activities.

The geographic distribution of the Applications Teams and the special problem areas in which each team concentrates are shown in Figure 2 and Table 3.

The Applications Engineering Center (AEC) is part of the Division of Biomedical Engineering, Research Laboratories for the Engineering Sciences, of the University of Virginia School of Engineering and Applied Science. This group provides an adaptive engineering capability in addition to that of the Biomedical Applications Teams. Its basic function is to adapt NASA technology to the needs of a Problem Originator, where the Problem Originator is unable to adopt the technology through his available resources. This recent program innovation was established in response to a continuous need for reengineering of aerospace technology to meet nonaerospace requirements.

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The two following chapters summarize recent achievements of the Biomedical and Technology Applications Teams Program. These summaries clearly indicate the significance of the specific problems, the relevance and application of NASA technology, and the complexities involved in achieving such transfers.

# ACCOMPLISHMENTS OF THE BIOMEDICAL APPLICATIONS TEAMS

## ACCOMPLISHMENTS OF THE BIOMEDICAL APPLICATIONS TEAMS

### TRANSFER ACTIVITY AND APPLICATIONS ENGINEERING EFFORTS

The Biomedical Applications Teams have successfully completed several significant transfers of aerospace technology during the period covered by this report. The transfers were a result of continuous cooperation between the physician, the aerospace engineer and scientists and the team member. These results demonstrate and affirm the active problem-solving technolgy transfer methodology as a means of providing effective communication between the diverse fields of medicine and aerospace technology. Furthermore, this NASA Program illustrates that effective channels have been established for the transmission of information, ideas and technology between the physical and medical sciences.

Potential transfers occur when the Biomedical Applications Team has identified a solution that the medical researcher feels will solve his problem. There are many inherent barriers to biomedical technology transfer; the time required to achieve an actual transfer -- a proven successful use of technology -- may vary widely. The overall effects of the potential transfers in the field of medicine will serve to add to the functional value of the Biomedical Applications Team program in the future.

For problem-solution matches which have reached the status of Potential transfers, NASA has undertaken applications engineering or equipment loan efforts, where appropriate, to assist the medical researcher in fabricating, obtaining, and evaluating the transferable aerospace technology. Detailed technical and biomedical criteria have been incorporated into the process of selecting projects to insure focus of this limited resource on significant problems which meet specific medical requirements. This section of the report is intended to provide a broad perspective of current Program activities. Applications engineering projects that are nearing completion, but which became potential transfers prior to the reporting period covered, are included.

Diagnosis of Infant Hearing Defects Aided by Improved Techniques for Electroencephalograms (EEGs). A space helmet utilizing unique sponge electrodes, originally developed by NASA's Ames Research Center to obtain electroencephalographic (EEG) tracings from astronauts and test pilots under stress, has been adapted for evoked audiometry to detect hearing defects in infants.

Thousands of children classified as mentally retarded are believed to be suffering not from mental retardation, but rather from hearing impairments which have cut them off from auditory rapport with their environment, a means of intercommunication that is essential to development of the intellect. Investigators at The Scott-White Clinic and Hospital at Temple, Texas, feel that if hearing defects can be detected early in infancy and appropriate remedial measures initiated, this can serve as prevention against many youngsters becoming functional retardates. These investigators have developed instrumentation whereby EEG signals would indicate whether or not a child reacts to an auditory stimulus. Because EEG electrodes attached to an infant's scalp by the standard method are often yanked off by him, means of preventing this action was needed.

When this problem was presented to members of the Southwest Research Institute Biomedical Applications Team they suggested use of the NASA EEG helmet. The Scott-White investigators considered the helmet a plausible solution to the EEG electrode problem where small children are concerned. After bioengineers at the Southwest Research Institute adapted the helmet for use by infants and delivered it to the investigators, it was successfully applied for its intended new use. The adapted EEG helmet not only provides for improved placement of EEG electrodes on the infant's scalp, but also provides earphones for the auditory signal. Members of the Southwest Research Institute Biomedical Applications Team are coordinating an effort to develop a refined instrument package, for measuring the child's response to the auditory signal obtained by means of the helmet.

Piezoresistive Semiconductor Functions As Heart Muscle Force Transducer For Heart Research. An outgrowth of semiconductor technology developed by a NASA contractor is now being used to measure muscle fiber membrane tension for better understanding of the mechanisms of the beating heart. For this same purpose, a physiologist at the Kansas University Medical Center has been studying the mechanical properties of membrances surrounding frog heart muscle.

The physiologist wanted to measure tension in the muscle fiber membrane, for which he needed a miniature force transducer. This would permit study of both electrical properties and mechanical properties of the tissue.

A member of the Midwest Research Institute Biomedical Applications Team discussed this problem with the Technology Utilization Officer at NASA's Ames Research Center, who furnished information on an Ames contractor who had developed a similar transducer for NASA. The information was relayed to the dKansas University physiologist, and he purchased the transducer by special order. It is currently being used.

The technology involved in the force transducer being used by the physiologist is identical to that which the contractor used. In space flight research, the contractor used a miniature triaxial accelerometer which was attached to the teeth of subjects exposed to simulated large accelerative forces.

The force transducer has enabled the investigator to further his investigations into the mechanism of electrochemical stimulation and mechanical contraction of heart muscle.

Early Detection of Arteriosclerosis by Determination of Arterial Pressure Pulse Wave Shape Transit Time. Arterial occlusive disease (arteriosclerosis) is a serious health problem in the United States; in 1965, 38,102 deaths were attributed to arterial disease. It can be alleviated or corrected through various techniques. A major difficulty is that it is extremely difficult to detect in early stages before serious damage has been done. The disease often reaches crippling or catastrophic proportions before it is detected. The numerous and severe consequences of advanced arterial disease frequently lead to death without advance warning. A researcher at Bowman-Gray School of Medicine expressed a need for means to detect occlusive arterial diseases early enough to arrest development.

The arterial pressure in the arterial system is a function of distance and time; hence it has wave properties. The wave speed of the pressure pulse is related to the eleastic modulus of the arterial wall. Also, wave reflections occurring in the arterial system perturb the pressure function. The elastic properties of the arterial wall change in humans with age and arterial disease. The biological problem is to detect, nondestructively, changes in the material properties of the arterial vessel, early in the process of arterial disease. Change of the properties of the arterial wall are thought to be related to wave speed or transit time of the arterial pulse. To validate the accuracy of this hypothesis it is necessary to establish the relationship between the extent of arterial disease and the wave speed or transit time of the arterial pulse. An accurate means of determining wave speed or transit time will aid in the determination of this relationship. Consequently, it is essential to obtain reliable, accurate means of determining the wave speed and transit time of arterial pulses.

The Research Triangle Institute Biomedical Applications Team suggested that an ultrasonic Doppler blood pressure measuring system developed by the Southwest Research Institute's engineers for NASA would be capable of making the necessary measurements. Although some alterations must be made to the original system they ar not extensive and can be made easily. A two-channel unit, now being built at SwRI, will allow the problem originator to establish relationship between arterial wall properties and transit time or propagation speed of the arterial pulse.

This device will be used to measure the arterial pressure pulse wave shape at two points along an artery and the transit time required for passage of the pulse from one point to another. If the pulse shape has changed downstream then a change in the dynamic elastic properties of the arterial wall could be suspected. By moving the measuring apparatus along the artery, local constrictions could be detected. If, during a series of such measurements along an artery, the wave shape broadened and the transit time increased as one progressed downstream on the artery, this might indicate the presence of diffuse arterial occlusive disease. Such an indication would be an invaluable diagnostic aid. If a physician can detect arteriosclerosis in its early stages, appropriate therapy can be initiated before irreversible damage developes.

Method of Controlling Rate of Freezing of White Cells For Leukemia Research. A "cold sandwich," designed by NASA engineers at the Jet Propulsion Laboratory, may prove useful in freezing white blood cells in blood banks to be used for leukemia patients.

Leukemia is a form of cancer characterized by proliferation of white blood cells which are formed in bone marrow. It is treated by killing the cancerous white blood cells in the blood and bone marrow with the use of drugs or radiation. This process can cause loss of all bone marrow, inhibiting the production of normal white cells, so that a fresh supply of white cells is required for the patient. It would be desirable to have a white cell "bank" or frozen storage facility to provide sufficient white cells for leukemia patients. Currently,

this is almost impossible due to destruction of white cells by existing freezing and thawing procedures, where the rate of temperature chage is inconstant. A method of freezing that provides for a constant rate of temperature change is considered the solution to the white cell destruction problem.

Researchers at the National Cancer Institute described the problem to members of the Research Triangle Institute Biomedical Applications Team. A detailed Problem Statement was then prepared by Team memers and distributed to NASA scientists and engineers associated with this field for their suggestions. A group of engineers at NASA's Jet Propulsion Laboratory responded with a design of a heating and cooling "sandwich" which provides for controlled cooling. The NCI researchers reviewed this system and are investigating ways of having it fabricated.

The controlled freezing unit consists of a Teflon bladder containing the white blood cells, surrounded by heater grids, which are in turn surrounded by a cold tank through which liquid nitrogen flows. A temperature sensor in the bladder would continuously monitor temperature of the bladder contents and transmit this information to modified Wheatstone Bridge circuitry. This, in turn, would control the heater grids to provide a constant rate of cooling by the liquid nitrogen. If this design proves successful, it will remove a major obstacle to the availability of white cell blood banks and will lead to improved care and treatment of leukemia patients.

Automated Measurement From Coronary Angiograms. Technology that was developed at NASA's Jet Propulsion Laboratory to enhance transmitted television images of Mars is being applied to techniques for measuring volume changes of the heart's pumping action. Under a current method for measuring heart volume, two x-ray images of the heart at right angles to each other are made after injecting a radio-opaque dye into the artery surrounding the heart. This allows measuring the changes in the volume of the heart by measuring the dimensional changes that take place outside of the heart, which can be measured by observing the changes in positions of the arteries surrounding the heart. The existing method for making these measurements is a laborious, manual process. Efforts are underway to automate this process. The Research Triangle Institute Biomedical Applications Team found information on the JPL image enhancement technique at the NASA Jet Propulsion Laboratory. This information was given to an investigator. Through a summer fellowship, he was able to spend considerable time at JPL where he learned the image processing procedures which he applied to his problem. He has since purchased equipment necessary to more efficiently analyze the angiogram data.

When this technique is perfected, it will be valuable in determining location and extent of loss of heart muscle function. It will also aid in determining effectiveness of surgical procedures designed to improve heart function by improving the blood supply to the heart.

Improved Lens For Cancer Research. In cancer research as is in other advanced medical studies the basic unit of study is the human cell. Medical science demands fuller information on cellular action, and technology frequently

plays a vital role in supplying information on intracellular components. A study being conducted at the National Cancer Institute uses an optical microscope controlled by a digital computer in order to obtain quantitative chemical data on cell mechanisms. It would scarcely be possible to pursue such a study otherwise, because of limitations of the human eye in detecting minute changes. The same system can be used to delineate three-dimensional architecture of the human tissue.

This study has been underway for some time, but there has been difficulty in obtaining sufficient light intensity with the existing unit, which could be overcome by using a complex elliptical lens. The researchers have not been able to locate a commercial source for the needed lens. The National Bureau of Standards is willing to grind the lens if grinding specifications for the complex surface are available.

A computer program of the Jet Propulsion Laboratory is equipped to design complex optical systems. This program has not designed elliptical lenses, but NASA personnel state that the work can be done. The Fortran language computer program was shipped from the NASA Computer Software Management Information Center (COSMIC) to the researcher, who is presently utilizing this means to design the improved lens.

The new elliptical elns will greatly clarify information derived from the human cell studies. The lens design is a critical tool of advanced technology to further cancer research.

Quantization of Heart Tissue Hardness. Post mortem examinations of various organs of the human body can reveal not only the cause of death, but often show other conditions that were affecting the person at the time of death. Research at Tulane's School of Medicine shows that in some cases, there was unusual softening of the heart tissue in patients who did not die of heart disease. The cause of this unusual softening is not known, but a number of factors are considered significant. For example, there is apparently a critical time period between the appearance of an infarction and a definite softeness in the heart tissue. Reasons for this are being studied in experimental work, using rats whose blood is temporarily cut off from portions of the heart in order to determine changes in the heart tissue. Studies are also being conducted on human hearts in autopsy examinations, to determine whether this soft region can be attributed to any known condition of the human prior to death. In order to carefully characterize these soft regions, a means of measuring softness of the heart tissue is needed. The researcher's use of a conventional eye tonometer for this purpose has not been successful; the results have not been reproducible.

The Research Triangle Institute's Biomedical Applications Team made a computer search of the NASA data bank for information on measuring hardness of soft materials such as sponge rubbers and plastics. This search turned up experiments conducted at the Marshall Space Flight Center on a variety of hardness testing techniques. These appeared to be applicable to this problem. The Team visited MSFC for discussions with program personnel and discovered that a number of techniques in current use at MSFC were also applicable.

NASA personnel indicated the type of instrument that was required for this purpose. Of greater importance, they outline the procedures necessary to obtain reproducible results. This information was then relayed to the physician at Tulane's School of Medicine, who purchased the instrument recommended and incorporated the suggestions in his testing procedures. The experiments are currently underway, utilizing the NASA techniques, and the results to date have been successful. However, the researcher has determined the need for a tester for smaller areas, and the manufacturer has agreed to fabricate a special instrument according to his specifications which will allow testing of very soft, small regions. The results of this experiment are expected to add considerably to present medical knowledge.

Bone Density Measurement. Neoplasms such as tumors often secrete hormones which leach calcium from the bone. This can produce hypercalcemia (excessive calcium in the blood) and can produce a site in the leached bone that is vulnerable for cancerous cells. Hypercalcemia affects approximately 20 percent of lung cancer patients and 40 percent of breast cancer patients. Although hypercalcemia can be treated, its fundamental cause is not known. Present studies on experimental animals use x-ray absorbtion techniques to measure bone density as a means of following the progress of demineralization. This technique is not desirable for humans, since it requires the patient's exposure to numerous large doses of x-ray which must be continued for long periods of time.

A researcher at the Ochsner Foundation is studying the demineralization process in rats. He requested the Research Triangle Institute's Biomedical Applications Team to determine if NASA has developed any techniques for determing the decalcification of bone. The Team found that the Marshall Space Center had constructed a device for just this purpose to be used in the NASA Skylab program. The propagation velocity of an ultrasonic pulse along the length of a bone is measured by this device. Since conduction velocity is a function of material density, it should provide a good indication of any changes in the composition of the bone. This is a non-destructive test and merely requires accurate positioning of two transducers in good contact against the skin overlaying the bone being examined.

The researcher will perform these measurements on the rat tibia, with bone dimension similar to the phalange bones of the human hand. It should therefore be possible to extrapolate his data and findings to measurements made on the phalange bones of humans in whom hypercalcemia is suspected. If the technique proves fruitful it will be important both as a diagnostic aid and to evaluate the efficacy and progress of thereapy.

NASA Seal May Improve Mechanical Respirators. A Lower Body Negative Pressure device (LBNP) was developed for the NASA Skylab program. Clinical adaptation of the device is being considered for use in reducing the approximate 1,500 polio confinements to Iron Lung unite. Adaptive engineering is required to provide a method of lung ventilation with the efficiency of the tank Iron Lung unit, and the mobility of the less effective chest shell unit. To provide the best ventilation and achieve efficiency and mobility, a neck-to-hips enclosure would have to be constructed.

Such a respirator must have an adequate seal for low negative pressures (which is available in the LBNP), and flexibility so that the patient can sit up as well as lie down. A negative pressure of from 0 - 40 cm of water is required at a breathing rate of about 15 - 20 times per minute to achieve an exchange of air in the lung of about one liter per breath. The Lower Body Negative Pressure device can be made to conform to the hip requirements and the necessary technology is available at the Manned Space Flight Center. Information on the device was made available to the investigators by the Research Triangle Institute Biomedical Applications Team. Applications engineering cooperation between NASA Center personnel and the Oschner Foundation will soon be initiated.

Ultraminiature Cardiac Manometer Serves as Blood Pressure Detector. A miniature diaphragm type capacitance pressure transducer that can be mounted on the end of a cardiac catheter is being prepared for commercial production. Its small size, sensitivity, and linearity represent a state-of-the-art advance in the measurement of intravascular and intracardiac blood pressure waveforms, and in the detection of high frequency heart and valve sounds. These pressure transducers were originally developed at NASA's Ames Research Center for use in wind tunnels as pressure survey probes and for the telemetry of pressure data from small free-flight models.

Models of the transducer intended for medical applications have been fabricated with diameters of 1.4 mm, 1.2 mm, and 1.0 mm. Mounted on the tip of 100 cm catheters, the pressure transducer may be introduced into an artery or vein through a standard 17-gage thin-wall needle (ID=1.1 mm), a size routinely used for humans. The pressure probe-tipped catheter can be easily inserted percutaneously through a needle. It will probably replace techniques which use fluid filled catheters for measuring ventricular heart pressures and those procedures which require cutdowns on arteries for the insertion of the catheter. Measurement techniques currently in wide use employ a fluid-filled catheter to transmit internal pressures to external transducers. These are subject to distortion and error introduced by the long fluid column through which the pressure pulse must propagate before being measured. The improved device will allow physicians to obtain a more accurate indication of the intracardiac pressure while reducing risk to the patient.

Because of its small size, the device can be inserted in small arteries, veins, and secretory ducts without greatly disturbing their fluid flow characteristics. This is an important consideration in measuring many biophysical parameters.

Liquid Flowmeter for Use in Kidney Research. A liquid flowmeter, developed by a NASA contractor may be used to measure urine flow in the human ureter.

To understand kidney diseases requires an improved understanding of the total urological system. In the urological system, the important ureter serves as the tubes that connect each kidney to the bladder. Urine flow measurements in the ureter, to obtain further understanding of urethral physiology, are the subject of a research study at the Washington University. An existing technique for measuring flow in the ureter requires collecting urine samples at definite times to calculate average flow rates. Investigators at the Washington University needed a technique for measuring instantaneous rates of urine flow in the ureter.

After a Problem Statement was submitted to all NASA field centers, the Research Triangle Institute Biomedical Applications Team learned of a NASA contractor who was working on a liquid flowmeter utilizing the hot thermistor approach. The NASA contractor and the Washington University investigators are currently arranging for fabrication of this flowmeter.

Biosatellite Animal Restraint Device to be Used in Arteriosclerosis Research. The primate restraints device used in the NASA Biosatellite Program is being studied for use in restraining primates who have been given test drugs to reduce or eliminate the effects of arteriosclerosis and other arterial diseases.

Arteriosclerosis is characterized by the buildup of extraneous material within the arterial system. This causes a reduction in the diameter of the artery thus reducing the amount of oxygenated blood being delivered to the body tissues. To regulate this reduction of blood flow to tissue, drugs have been used to dilate or expand the arteries in order to compensate for buildup of material on the arterial wall.

A great deal is not yet understood about the mechamisms and effects of the vasodilator durgs. Investigators at the Bowman Gray School of Medicine of Wake Forest University have begun an extensive program to compile more information on these drugs and thus to permit more effective use. The research program has progressed to the point of determining the effects of various vasodilators on monkeys for periods up to six months. Since instruments will be used on the monkeys to measure blood flow, blood pressure, temperature, and electrocardiograms, the Bowman Gray investigators need a means of restraining the animals from activities that would impair or damage the instrumentation.

The problem was discussed with the Bowman Gray investigators. The Research Triangle Institute Biomedical Applications Team then contacted the researchers at NASA's Ames Research Center who developed the primate restraints devices for the Biosatellite Program. Detailed plans and advice on the restraint device were provided to the Bowman Gray researchers, who are evaluating the Ames device and considering means of fabrication.

Detection of Eye Tumors by Use of Radiation Probes. There is a problem in detecting concentrations of weak beta radiation from an isotope administered to patients when an eye tumor is suspected. The isotope is selectively absorbed by the tumor cells. It is necessary to differentiate between different levels of radiated energy to detect tumors which are hidden from direct observations, or are in such an early stage of development that they can not be detected by ny other means. A mea suring technique being used requires insertion of a dime-sized Geiger counter probe between the eyeball and the eye socket. The probe is both excessively large and insufficiently directional to be optimally sensitive, and cannot adequately determine the size of the tumor. Thus there is some danger that its inaccuracy will engender removal of an eye that could be saved. A semiconductor radiation probe developed by NASA is sufficiently small to put in a slender probe; it can be inserted easily into the area behind

the eye with minimum trauma. The probe has a signal-to-noise ratio that is amenable to recording equipment, and provides a realistic measurement of the spatial and energy distributions of beta radiation. It is highly sensitive. From the data gathered from many locations, the differences in isotope concentration can then be used to identify and outline the area of increased isotope uptake by suspected tumor cells, if they are present.

This information will be vital to diagnosis and therapy of the eye. More accurate determination of the distribution of the isotope ty the clinician will make his disgnosis more accurate. This will reduce the present high percentage of false positive-tumor diagnosis, which in turn erroneously causes removal of the eye. The Southwest Research Institute Biomedical Applications Team is installing the radiation detector in a specially designed probe. It is also designing an instrumentation package to connect this device to various display and analysis systems.

Pressure Sensitive Device for Use in Tongue Operated Control Systems for Assist Devices and Wheelchairs. Severe neuromuscular disabilities are frequently fatal, but survivors are often faced with the prospect of being bedridden. Improved patient care has increased the number of patients who survive severe paralysis. Such patients are greatly limited functionally, hence dependent on society. Dependency relates in part to the extent of disability, and to technological devices and methdology to develop self-sufficiency. Total care for paralytically disabled patients is very expensive. Researchers at the Rancho Los Amigos Hospital developed high specialization and competence for for innovating a great variety of orthopedic methodologies and devices. They are working with neuromuscular patients severely disabled and amputee patients with the same requirements for care. The development of self-sufficiency for mobility is a major interest. The wheelchair can be equipped to provide mobility and self-sufficiency. The basic wheelchair has been modified to add the efficiency of electric motors with various switches and attachments where required. A wheelchair can now be operated forward or backward, can turn, and go up and down inclines or stairs by means of added devices. The researchers are attempting to refine control and operation so that the wheelchair can be used by paralyzed or amputee patients whose use of muscles is limited to those of the eyes, mouth, and head. Considerable progress has been made in developing control systems for externally-powered orthotic devices. Extra-oral, tongue-operated switch controls provide sequential off-on control of the orthesis, and show promise as a means of providing control. The Problem Originator requested assistance from BATeam personnelfor technology adaptable to incorporation in a reliable, saliva-resistant switch that is small enough to fit the lingual area of the mandible, and sensitive to tongue pressure operation. The BATeam identified a suitable device through a NASA Tech Brief. The device is an insulated-gate field effect transistor, which can perform strain sensing and amplification functions in one hermetically sealed, integral package. The Problem Ooriginator plans to incorporate the device into a switching unit which will vastly improve on the the control devices currently in use. It will permit the chair operator to achieve controlled gradual accelerations (and decelerations), a feat not possible with current on-off control systems.

Beta Radiation Catheter Probe. There is a need for a technique to continuously monitor the cerebral blood flow of head injury patients over an extended period of time. Present techniques require inhalation of a radioisotope and the withdrawal of many blood samples for analysis to determine arterio-venous concentrations of the isotope. Monitoring of cerebral blood flow is necessary to determine therapy effectiveness. This technique produces patient discomfort and requires cumbersome equipment which must be maintained in a sterile condition and it provides few data points for assessing the blood flow, yet continuous determinations over extended time periods are needed to provide optimum analytic effectiveness. A semiconductor radiation probe capable of continuously monitoring blood flow by detection of weak beta radiation from the isotope was developed by NASA. It can be mounted in a small double lumen catheter, making it easy to insert at the proper point in the blood stream. The probe has a low signal-to-noise ratio and provides good measurement of the spatial and energy distributions of radiated electrons and protons. The use of this probe will enable the physician to continuously obtain data. One catheter-mounted probe would be placed in the carotid artery to monitor the isotope concentration in the blood being supplied to the cerebral area. (A lumen located near the tip of the radiation probe would allow one blood sample to be taken for blood gas analysis). A second catheter-mounted probe with appropriate lumen would be placed in the jugular vein to get a similar measurement on blood flowing from the cerebral area. From the data collected at these two points the cerebral blood flow is easily determined; the blood flow data are indications of the extent of head injuries, progress towards recovery and the effectiveness of therapy. The radiation probes are being mounted in suitable catheters by the Southwest Research Institute BATeam who will also provide the investigator with the necessary electronic devices. The system will then be treated in several animals before being given to the physician for clinical trial and evaluation.

Tidal Volume Measurements in Respiration Studies Improved By Venturi Transducer. Studies for definition and diagnosis of emphysema and other respiratory diseases require quantitative information on tidal volume (volume of air inhaled and exhaled) in conjunction with other physiological paramters. In his investigations, the medical researcher exercises his subjects while attempting to measure their tidal volume with a high-resistance transducer (pneumotachograph). The combined effects of the condition of the patients and a high-resistance tranducer drastically increased the respiration work load so that experiments were terminated. The investigator's overall goal was to acquire a resistance-free instrument that would automatically measure tidal volume. His immediate goal was to develop a resistance-free airflow transducer that would enable him to continue his research.

The Southwest Research Institute Biomedical Applications Team provided a solution for both problems based on an article from the NASA Data Bank. This paper, entitled "Tidal Volume Air Measurement," describes an automatic monitor which incorporates a small stainless steel venturi transducer that is obstruction free. It provides a solution to the air resistance problem and it is automatically operated. The researcher plans to fabricate a prototype venturi from glass, increase its dimensions for human use, and incorporate a skin diver's snorkle mouthpiece. The venturi assembly will be used and calibrated as descirbed in the paper retrieved from the NASA Data Bank.

Interfacing Biochemical Autoanalyzers with a Computer. The Problem Originator wishes to interface several biochemical autoanalyzers used in the Pathology Department of St. Joseph's Hospital with computers to increase the efficiency of specimen analyses. This would help achieve cost savings for laboratory services which could ultimately be passed along to the patient. After defining the problem, the BATeam investigated the computerized diagnostic facilities at the NASA Manned Spacecraft Center (MSC), and found that much of the required technology and computer programs were available. Arrangements were made for the Problem Originator to attend a seminar at MSC given by Dr. E.C. Moseley concerning the center's Medical Information Computer Systems(MEDATA). Arrangements were also made for the Problem Originator to meet with Dr. Craig Fischer, head of the MSC Medical Directorate's clinical laboratory. As the result of these meetings, the Problem Originator was confident that if he could obtain the computer programs and related data, he would be able to adapt them for use at St. Joseph's Hospital.

Working through the MSC Technology Utilization Officer, the Southwest Research BATeam arranged to obtain (1) a listing and magnetic tape containing all MEDATA-related programs now in operation at MSC, (2) technical documentation of these programs, and (3) a document describing the overall system. These have been transmitted to the Problem Originator for use in adapting his less sophisticated computer system. The Problem Originator's enthusiasm and resolve will help to shorten the time ordinarily required to adapt the complex programs.

Information Retrieval System for Clinical Records. A southwestern medical facility having 80,000 annual admissions needed a means of retrieving information from its bank of one half million records. The hospital particularly desired access to information which would determine effects of specific medical treatments, enhance disease prevention, and identify trends in medical treatments. The ideal system would permit patient record updating as patients return for treatment. Ultimately, it was desirable to perfect computer analysis techniques for providing guidance in treatment of unusual diseases. The hospital had sophisticated data processing equipment but lacked computer programs to accomplish the desired tasks.

The Southwest Research Institute BATeam arranged a briefing for hospital personnel at the NASA Manned Spacecraft Center Medical Research and Operations Directorate. NASA had originally developed several computer programs for the storage of aerospace medical data and data on the medical history of all of the astronauts. These programs allow for the storage of medical records in a form suitable for retrieval of medical data according to specification and for updating of the medical data bank. Arrangements were made for the hospital to receive program documentation, enabling the testing and evaluation of the programs for use in their system.

Measurement of Surgical Suite Contamination. An instrument modified by a NASA contractor for use in monitoring airborne contamination in rooms where spacecraft components are fabricated is now being evaluated for similar use in hospital operating rooms.

A clean room system is being installed in an open-heart surgery operating room at the Washington University Medical School Hospital. Instrumentation was required to monitor airborne particulate matter in the operating room to determine the clean room system's effectiveness. After definition of the physician's problem, the Midwest Research Institute Biomedical Applications Team searched the NASA Aerospace Data Bank and found a potential solution. This was an automatic aerosol particle counter, modified by the IIT Research Institute under contract to the Marshall Space Flight Center, for use in the Goddard Space Flight Center Manufacturing Engineering Laboratory. This instrument was found to be an acceptable means of measuring airborne contamination. It provides a continuous readout of contamination levels, enabling variations in contamination to be correlated with events occurring in the operating room.

Telemetry System Permits Dentists to Measure Tooth Pressures. A miniature telemetry system, developed at Ames Research Center, will assist dental researchers in their evaluation of tooth stress under chewing conditions.

The University of Iowa School of Dentistry has been conducting research on the determination and measurement of stress to teeth. Damage and perhaps eventual loss of teeth may occur folowing corrective dental work unless pressure points are detected and adjustments made to prevent permanent tooth damage. Measurements obtained by this telemetry system will be useful for stress determination in natural teeth that have corrective dental work and will also facilitate adjustments of orthodontic devices.

Used with a commercial tranducer, the telemetry unit meets the necessary dentistry requirements: it is self-contained, has an internal power supply, can operate for at least two hours without battery recharge, and can be built to fit under the tongue. The demodulator needed to process the telemetry unit's signal was built by the same researcher after he obtained a detailed description of appropriate NASA-developed circuitry. Both pieces of equipment were located by the Midwest Research Institute Biomedical Applications Team through a search of NASA Technical Reports and a review of supplemental information.

Cleft Palate Airflow Monitor. The determination of the severity of the cleft palate and the effects of corrective surgery can be evaluated by measuring the amount of air passing through the nasal opening during speech. This air flow parameter has been measured, but the equipment used is generally expensive and requires the use of a mask over the patient's nose.

The NASA respiration monitor, as described in NASA Tech Brief B68-10438 and supplemental information, will be useful for gross measurements to estimate the amount of air flowing out the nasal openings. A duplicate model of the NASA respiration monitor was constructed and forwarded to an investigator at the University of Minnesota Dental School for his use. The monitor, in its original configuration, will not measure air volume directly but the investigator feels that it will be useful as a supplemental measuring device for preliminary investigations.

Remote Patient Monitoring Technology Aid in Rural Medical Program Feasiblity Study. NASA reports describing instrumentation technology, originally developed to monitor physiological processes of astronauts in space flight, are being used in a feasiblity study of remote patient diagnosis and care for rural areas.

Investigators at the University of Minnesota have undertaken a feasibility study to determine available technology capable of providing rural citizens the benefits of a regional medical program without requiring them to travel to a central clinic. These investigators are examining the applicability of computer technology, closed circuit television, remote physiological monitoring systems and other similar technology.

Reports of 19 major technological advances in physiological monitoring developed for NASA's space effort were located by the Midwest Research Institute Biomedical Applications Team in a NASA data bank search. These developments are relevant to this problem. If these developments and other technology located by the Minnesota investigators show remote patient diagnosis and care approach to be feasible, their program will enter the demonstration phase.

Charging Systems To Prolong Life Of Nickel-Cadmium Batteries Used In Prosthetic Devices. NASA conducted research and development to design efficient batteries for powering space-borne systems. The fruits of these efforts are being used in development of a motorized prosthetic device. Investigators at the University of Minnesota's Department of Rehabilitation and Physical Medicine have developed a prosthetic device which is attached to a patient's crippled arm. An electric motor supplies power to the device's finger support members, enabling the patient to close the fingers with force sufficient to grasp objects. Excessive discharge of the cells, polarity reversal, and a diminishing of cell charge capacity were problems encountered with the nickel-cadmium batteries used to power the motor and related circuitry. The investigators needed help to overcome these problems in the nickel-cadmium batteries and prolong their life.

An extensive NASA document on space batteries was obtained by the Midwest Research Institute Biomedical Applications Team. It was provided to the investigators who are using the information to improve their ability to use nickel-cadmium batteries.

Measurement of Battery Drain from Powered Prosthetic Device. An electrically powered hand prosthetic device was built at the University of Minnesota. The device uses rechargeable batteries as a power source. The battery power drain is determined to a large extent by the amount of work that is done. It is important to protect the rechargeable (nickel-cadmium) batteries to prevent damage and short life due to over-discharge. A NASA document titled "Mercury Electrochemical Coulometer As a Battery State-of-Charge Indicator" describes the use of mercury electrochemical coulometers to measure the conditon of secondary rechargeable cells. This type of coulometer is being installed in one of the powered hands. It will provide an indication of the power cells condition based on the amount of current taken from them.

Aerospace Valve For Urinary Control. Certain injuries and diseases cause the loss of voluntary control of the urinary function. In addition to obvious social and hygenic implications, the inability to control urine flow can result in kidney tissue deterioration, infection, and in some cases, kidney damage and death. Attempts to overcome this condition, by using electrical stimulation of the flow-controlling muscles have not been wholly successful because of insufficient muscle response and painful bladder pressure.

A medical researcher treating paraplegics found that there was a need for a simple, reliable, and totally implantable urethral valve which could be easily controlled by the patient. A NASA engineer suggested that a valve similar to one used in manometer tubes might solve the problem. This valve has been included in the design of an implantable control system. This system will enable the patient to mechanically control urination by applying pressure to a small air-filled bulb located under the skin. Bio-compatible materials such as silastic normally used for long-term implants were unsuitable as they react adversely to continuous exposure to urine. A material has been found by the NASA Applications Engineering Project and preliminary tests indicate it is bio-compatible and capable of withstanding constant exposure to urine. Difficulties were encountered in fabricating tubing and bulbs out of the material but these techniques have been mastered. Five prototype urinary control systems have been fabricated.

These prototypes will be implanted in dogs to determine if there are any unfavorable long-term interactions between body tissue, the tubing and valve material, and urine. If the prototypes prove satisfactory, the design would be inexpensive to manufacture and could benefit as many as 15,000 patients per year.

Improved Photographic Emulsion To Be Used In Cancer Research. An improved photographic emulsion, being studied at NASA's Goddard Space Flight Center, is now being prepared for use in detection of radioactive cancer cells. The study of cancer in experimental animals can be facilitated by labeling the tumor cells with radioactive tritium. The tritium attaches itself to the DNA molecule and the division of the tumor cell produces new labeled cells. A process, called autoradiography is used to detect a radioactive cell; a film sheet of photographic emulsion is placed over the cell and exposed by the radioactivity. Existing emulsions require an exposure of a month or more of exposure time. Investigators of the National Cancer Institute (NCI) need a faster high resolution film so that the autoradiography technique can be used clinically to evaluate the progress of cancer in humans.

The Research Triangle Institute Biomedical Applications Team placed the NCI investigators in contact with a scientist at the Goddard Space Flight Center who is preparing an improved emulsion for testing at the NCI.

Non-Invasive Continuous Monitor Detects Onset of Shock. Leukemia is a disease characterized by a self-perpetuating proliferation of white blood cell-forming tissue. An extensive National Cancer Institute program is directed toward finding the causes and cures of leukemia. The clinical phase of this program is concerned with early detection of shock. Shock, defined as the sudden

reduction in the volume of circulating blood, frequently results from hemorrhage, infection, as well as other causes. If it is not recognized early, the damage is irreversible and rapidly becomes fatal. Thus a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken in time.

An important measure of the onset of shock is reduction of blood pressure. The usual means of measuring blood pressure is by placing a cuff around the arm which is then inflated to higher than maximum blood pressure and slowly reduced. This method is quite inadequate for continuously measuring blood pressure if a patient is critically ill, since it disturbs him.

A device for measuring relative blood oxygen content has been identified, the ear oximeter, which permits detecting the onset of shock without disturbing the patient. The ear oximeter was developed for use in the early astronaut program; it fits the ear similarly to a hearing aid. Shock is evidenced by reductions in blood pressure, oxygen content of the blood, and peripheral circulation. The device is comprised of a small sensor mounted in the ear, and a small electronics package which can be placed at the patient's bedside. The absorption of infrared radiation by the blood is directly related to oxygen content of the blood. The onset of shock is accompained by a reduction in the amount of blood and the oxygen content of the blood flowing through the earlobe. Change in the infrared absorption is detected and causes the device to set off an alarm that warns medical personnel to take corrective actions.

The Ames Research Center has loaned the oximeter to the National Cancer Institute where clinical tests are underway to evaluate the unit. If the evaluation is successful, the unit will provide improved monitoring for leukemia patients.

Breathing Monitor. To ease breathing in infants, comatose children, or adult patients, surgical implantation of a tracheotomy tube in the windpipe is sometime required. If the tube is clogged and cuts off breathing, brain damage or death can result within 2 to 4 minutes. Use of the tube ordinarily requires a nurse constantly to check the tube and take immediate corrective action if necessary. Integrated circuitry, designed and fabricated for aerospace use by NASA's Ames Research Center, has been incorporated in a small device to monitor the temperature of air passing through the tube, and to actuate an audible/visible alarm within 10 seconds of any change. The alarm can be seen or heard at a nurse's station, or in another room if the patient is at home.

The breathing monitor is based on an automatic air surveillance system that was developed by NASA scientists. It has a temperature sensor/FM transmitter which is attached directly to the tracheotomy tube so that the inspired and expired air flows directly over a thermistor temperature sensor. Changes in the airflow temperature produce changes in the sensor resistance. An FM receiver records the respiration signal which in turn triggers the alarm system if reuired. The voltage changes caused by respiration are amplified and actuate an electronic switch. The switch provides a reset pulse for each respiratory

cycle that is of sufficient length, which is determined by setting the amplifier gain control. The reset pulse discharges the capacitor which serves as the timing element of the alarm control. If the capacitor does not receive a reset pulse for a preselected time (arbitrarily chosen as 10 seconds), an alarm control actuates an audible/visual alarm.

The device fabricated at NASA's Ames Research Center is on loan to the Institute for Rehabilitative Medicine in New York for clinical evaluation.

Tunnel Diode Transducer Used as a Biomedical Sensor. The human body is dependent on several fluid transport systems for moving nutrients, wastes, gases, enzymes and hormones from one part of the body to another. Blockage or excessive pressure within one of the fluid transport systems can result in various pathological conditions. Diagnosis and determination of proper therapy could be improved if a small pressure transducer (less than 1 mm. diameter) with proper sensitivity and range could be inserted into the numerous small ducts that make up the various fluid transport systems. Such a transducer would be valuable in assessing the condition of the circulatory (blood), cerebrospinal, lymphatic, and urinary systems.

Research and development at NASA's Electronics Research Center developed a suitable pressure sensor. New semiconductor fabrication techniques were utilized for a transducer with resolution of greater than 0.1 mm Hg with an overall diameter of less than 1 mm. and low power requirements, which has been designed, fabricated and tested. Since the NASA Electronics Research Center was closed last June, the researcher has formed his own company and is preparing to make this device commercially available. This device will greatly aid many investigators concerned with measurement requirements. The frequency response of this device is flat to greater than 4,000 hz. When it is mounted at the tip of a cardiac catheter, intracardiac sounds and pressures can be detected, providng valuable data in assessing vascular and valvular dysfunction.

The device will be useful in clinical diagnosis, monitoring, and animal research. In programs underway, this pressure transducer will be used to measure spinal fluid pressure and the pressure within the ureters, which are the thin tubes that carry urine from the kidneys to the bladder.

Wright Spirometer To Aid Surgical Anesthesia Monitoring. The Wright Spirometer modified by NASA to measure the respiration rate and volume in test pilots, shows potential application to monitoring respiration of surgical patients under anesthesia.

An anesthesiologist at the Kansas University Medical Center noted the problem of continuously observing the respiration state of an anesthetized patient. The anesthesiologist saw a need to accurately monitor the breath-by-breath respiration volume and flow rate of patients undergoing surgery, for an instant indication of their well-being and for a permanent record on the patient. The modified Wright Spirometer, developed by a contractor to NASA's Flight Research Center, was identified and suggested to the investigator by the Midwest Research Institute Biomedical Applications Team.

Preliminary tests of a prototype spirometer in the intensive respiratory care unit at the Massachusetts General Hospital are favorable. They indicate that while this instrument is in need of modification, it would provide valuable information, heretofore unobtainable, on patients' respiratory functions.

A suitable modified spirometer is being fabricated at the University of Virginia's Division of Biomedical Engineering as part of their NASA-funded Applications Engineering project.

Strain-Gage Transducer To Be Used In Occupational Therapy. Strain-gage technology from a NASA contractor is being applied to the measurement of force exerted by hand and arm muscles of physical therapy patients.

Many of the exercise and therapy routines at the Hand Rehabilitation Center of the University of North Carolina Medical School require that the patient exert a small amount of force against a static load. Frequently a patient is not able to exert a force that is measurable by standard means, but it is helpful to know if any force has been exerted by means of the muscles in question. Investigators at the Hand Rehabilitation Center needed a small, multipurpose, pressure-sensitive indicator that can be placed at the point of pressure application to indicate when the patient is exerting force by using his muscles.

Members of the Research Triangle Institute Biomedical Applications Team discussed this problem with a scientist at NASA's Langley Research Center. He suggested that the Team contact a NASA contractor who develops and manufacturers transducers. The contractor said that strain-gage transducer technology is available, and reengineering specifications are being developed.

Materials For Prevention Of New Decubitus Ulcers. A NASA scientist at the Ames Research Center suggested adapting a resin cushion material, which was used by a NASA contractor for aircraft seating, for medical purposes. The material is being fabricated into special pads and seats for the prevention of body sores (decubitus ulcers). Such sores are caused on patients confined to wheelchairs or beds, by the continued unequal distribution of body weight at pressure points.

The unique resin material has a resiliency that can shape itself to the exact contours of the body, thereby evenly distributing body weight. This material should help to alleviate a chronic medical problem. It is being evaluated by Rancho Los Amigos and the Texas Institute for Rehabilitation Research. It is also under consideration by the Hot Springs Rehabilitation Center.

## SPECIAL OPPORTUNITIES FOR BIOMEDICAL TECHNOLOGY TRANSFER

Many special and/or unique opportunities for technology transfer arise during the course of the Biomedical Applications activities sponsored by the Technology Utilization Office. There may be occasions for direct utilization of technology, development of technology relevant to a biomedical problem, or for the highly specialized and creative skills of NASA personnel. Opportunities stem from problems initially defined by the Biomedical Applications Teams, NASA groups,other

Government agencies, biomedical organizations other than participants in the Program, or qualified individuals needing NASA's assistance. For all technology transfers, NASA in-house or contractor capabilities were identified when directly applicable to problems. Transfer opportunities discussed here were not included in the applications engineering portion of the preceding section.

Bedside Biomedical Computer. NASA's expertise in microprogramming will prove valuable in developing a small computer for individual patient data storage and analysis. A small individualized computer to process direct and indirect data from a human subject will be developed by investigators at the Massachusetts Institute of Technology (MIT); the bedside biomedical computer will utilize inexpensive, commercially avaiable hardware. NASA will support software development by adapting software from the minicomputers of the Apollo program. A bedside data acquisition/analysis/display unit should help the hospital physician in his diagnoses.

Eyeswitch Operated Wheelchair. A device developed by NASA has been modified for the use of quadraplegics in wheelchair control. The original device was developed to permit astronauts to contro space vehicle flight under high gravitational force by the movement of their eyes. Known as the eyeswitch, the device consists of an infrared sensor and a light source mounted on a pair of eyeglasses. It can activate switches by using the light source to detect the difference between the light and dark portions of the eye. In the wheelchair, switches activate or deactivate motors which propel and direct the chair. Two eyesswitch-operated wheelchairs are in use at rehabilitation centers where they are being evaluated.

Prosthetic Hand. Servomechanism and electronics technologies were specially developed and applied for NASA in development of a Mechanical Activated Triggered Hand (MATH) for use in teleoperator application by astronauts. The MATH device is now being modified for use in rehabilitation and should permit an amputee to hold and operate power tools such as electric drills. The Technology Utilization Office of the Marshall Space Flight Center is working with the Rancho Los Amigos Hospital, a rehabilitation center, to utilize this NASA technology to further develop a prosthetic hand.

Biocarbon Implants. High-purity, high-strength forms of carbon, developed through aerospace research, are being used in the fabrication of prosthetic devices. Devices such as bone substitutes and replacement heart valves are intended for long-term implantation in the human body. Carbon is highly compatible with body fluids and tissues, but until recently, the carbon available was not sufficiently strong for prosthetics use; materials of lesser biocompatiblity had to be used.

Preliminary studies show that carbon forms developed for aerospace use are sufficiently strong to be fabricated into prosthetic devices and pure enough to be biocompatible. Technology Utilization funds have been made available to the Marshall Space Flight Center for a special project to further develop and test biocarbon materials in cooperation with interested medical specialists.

Medical Monitoring Chairs. NASA scientists and engineers have been investigating the use of instrumented chairs as a means of monitoring physiological parameters of astronauts when they are not wearing space suits. The technology may have important ramifications for mass health screening.

This technology was utilized by a NASA contractor to develop a prototype medical monitoring chair. This chair records physiological data such as electrocardiograms, galvanic skin responses, and heart and breath rate from a seated patient without the encumbrance of wires or attached electrodes. The chair is being evaluated by the Department of Clinical Engineering of the George Washington University Medical Center in their multiphasic health screening facility. Further development of the medical monitoring chair will make use of technology resulting from a biomedical engineering summer institute for engineering students sponsored by Goddard Space Flight Center.

Goddard Space Flight Center's Second Annual Summer Institute For Biomedical Research. A unique program to further accelerate the flow of NASA aerospace technology toward application to problems in biomedicine was undertaken this summer for the second year in a row -- The Summer Institute for Biomedical Research in Technology Utilization.

The Institute was a joint project of the George Washington University and NASA's Goddard Space Flight Center. It was undertaken to enable ten senior undergraduate engineering students selected from a number of engineering colleges throughout the eastern United States to spend ten weeks in an active technology application program. The students were able to apply their engineering background and aerospace technology toward solution of defined biomedical problems under the direction of University faculty and Goddard scientists and engieers. The Summer Institute was funded by the Technology Utilization Office of the Office of Industry Affairs and Technology Utilization, NASA Headquarters.

During the first half of the ten-week period, the students spent two afternoons each week in a classroom lecture series designed to provide them with a broad, comprehensive view of the biomedical engineering profession and, in particular, the systems engineering approach to health care. The lectures, seminars, and demonstrations were conducted by the George Washington University Department of Clinical Engineering in Washington, D.C.

Five well-defined research projects were developed by the Department of Clinical Engineering. These projects were focused on ideas, concepts, or existing instrumentation which needed further design and engineering improvement, so that significant progress in terms of working prototypes, could be accomplished by the students during the ten-week program. These projects were:

- Electrocardiographic Electrodes for Rapid Application

  To develop an electrode suitable for a 12-lead electrocardiogram system that can be applied rapidly and provide good short-term (less than five minutes) performance.

- Heart Sound Microphone Miniaturization and Improvement

  To improve the design of microphones for detection of heart sounds, within the constraints of low cost, appropriate size, and low signal-to-noise ratio.

- Heart Sound Envelope Circuit

  To develop a new or improved circuit to simplify the phonocardiogram (heart sound) signal so that a true sound intensity signal is created for more effective use in diagnosis.

- Digital Realization of Pulmonary Screening and Motivating Device

  To develop a digital circuit equivalent of an analog computational device used to overcome the difficulties of patient motivation and of rapid separation of normals from abnormals in pulmonary screening.

- Intensive Care Alarm Indicator System

  To develop a device which can be worn by responsible hospital staff personnel and will indicate when alarms on monitoring equipment have been activated.

The students were divided into five two-man teams and each team was assigned a laboratory area, a Goddard technical advisor, and one of the defined research projects. The students worked at their own speed, but were required to record all data in a research notebook. Sophisticated testing equipment, tools, supplies, and parts were made availabel to the students for their research.

Much of the prototype equipment designed and fabricated by the students during the Summer Institute is now in actual use and under further development by the George Washington University Department of Clinical Engineering.

More detailed information concerning the 1970 Summer Institute will be included in a report to be issued by the Technology Utilization Office of the Goddard Space Flight Center.

## OTHER TEAM EFFORTS

To solve a problem often entails much more than designing a piece of equipment or providing the details of similar problem solutions. The optimum solution to many problems require that the teams establish contact with specialists outside NASA. The research of outside specialists often help to lead to the solution of problems.

A surgeon who needed material to implant in infants for proper drainage of cerebrospinal fluid requested assistance from a BATeam. The team was not able to locate applicable NASA technology but it knew of Project Thrombus at the Cornell Aeronautical Laboratories. The project was concerned with materials for

implantation, treated in a way so that blood clots would not form. The team put the surgeon in touch with the researcher, and close cooperation should result in the design and test of a shunt in a relatively short time. Nonaerospace technology which is medically related was identified by a team as applicable to a kidney perfusion pump. A small, light weight pump of high reliability was used to circulate vital fluids through a kidney while it was being transported from the donor to a recipient. A miniature pulsatile pump developed by the Army Research and Development Command was identified. The team is arranging loan of the Army pump to the researcher for further evaluation.

The teams' broad experience and contacts frequently help in providing information to researchers. Time and effort is concerned, and the time required for medical development is reduced.

In the transfer of aerospace technology, the teams have been working with the Social and Rehabilitation Service (SRS) of the Department of Health, Education, and Welfare. The Rehabilitation Research Branch of SRS is concerned with improving techniques to benefit the physically or mentally handicapped. Areas of the program to which the BATeams are contributing are:

Portable, lightweight, powered wheelchairs
Pressure-sensitive devices for wheelchair control
Electromyographic muscle trainers
Lighweight, high-strength designs for artificial limbs
Special resins for cushioning materials
Strain gages for evaluating and fitting prostheses
An implantable valve to restore control of urinary function.

Some of these contributions have been described in previous sections of this report.

# ACCOMPLISHMENTS OF THE PUBLIC SECTOR APPLICATIONS TEAMS

## ACCOMPLISHMENTS OF THE PUBLIC SECTOR APPLICATIONS TEAMS

### TRANSFER ACTIVITY

The use of Applications Teams for public sector problems is a relatively recent Program innovation. The detailed knowledge gained from the Biomedical Applications Teams' experience in regard to transfers has benefited this part of the Program. A number of potential solutions to problems have been presented to Problem Originators in public sector agencies. Such potential solutions in several cases have reached the stage of complete agreement between the Technology Applications Team (TATeam) and the Problem Originator, indicating that a particular NASA technology applies to the problem, although further work is usually required. This work is necessarily accompanied by delays in time due to a variety of circumstances, for example, requirements for adaptive engineering, performance trials, procurement efforts, descriptive documentation for concerned parties, and other delaying factors. However, such transfers of available advanced technology usually result in substantial savings of time, effort and money when compared with the time and resources which would be required to initiate new research and development to solve a particular problem.

During the period covered by this report, a number of potential transfers have reached the stage of adaptive engineering and performance test evaluation. Once the Problem Originator has accepted the concept and a physical model is available for test, evaluation, or adaptation, the preliminary phase of the transfer is complete. The discussion here will center on the TATeam efforts to bring a specific item of technology to the preliminary transfer stage of the transfer process.

Detection and Recovery of Indented Writing. The President's Commission on Law Enforcement and Administration of Justice, established in 1965, found that the scientific and technical revolution that boosted the space program had little effect in the provision of support to law enforcement or criminalistics. However, several law enforcement and criminalistics problems have been identified for which solutions are likely to be found based on aerospace technology. One such problem involves the "Detection and Recovery of Indented Writing." Indented writing is the impression left on an underlying sheet of paper, blotter, or similar material while writing on the top sheet. The detection and recovery of indented writing is particularly difficult, but often important to the solution of criminal cases and to subsequent judicial procedures. To the television viewer, the solution to this problem may appear simple, such as making a pencil rubbing. But such a solution seldom works. Thus, any means of assisting in detecting and recovering indented writing will have lasting usefulness.

A potential method adaptable for the detection and recovery of indented writing, which is an alternate usage of a space program technique, was devised by Metro Physics, Inc., while under contract to the NASA Marshall Space Flight Center. Metro physics, Inc. developed a fiber optic device intended to detect

surface flaws and cracks on spacecraft components. The principle involved appeared to have application to the detection-recovery problem, since the indented writing is analogous to surface flaws or cracks on the medium.

Though the agency which identified this Problem was the Chicago Police Department, the Law Enforcement Assistance Administration (LEAA) of the Department of Justice showed an early interest in the problem and provided $3000 to Metro Physics, Inc. for a feasibility demonstration. Funds for this effort were not available from the Chicago Police Department.

Metro Physics began the necessary modifications to their device and started a test program in August, 1970. The test, completed in October, showed that further modifications were required. Specifically, because of translucency of the test paper, there was light scattering within the paper that resulted in background noise. Efforts to rectify this were successful to a degree. The TATeam then demonstrated the device to Chicago Police Department officials including personnel from the Documents Laboratory, all of whom were impressed with the potential of the device. The Chicago Police Department retained the device for one week for further evaluation under operational conditions. Late in October the device was demonstrated to the LEAA with favorable reception from technical personnel who understood the limitations and potential of the device.

The Chicago Police Department is presently preparing a detailed statement of their intended operational use of the device, and the improvements required. A report for NASA and LEAA, being prepared by the TATeams, will form the basis for further development leading to a fully operational device. Several significant features of the technology transfer process were demonstrated by this one effort. Foremost is that many Problem Originators lack funds or facilities, or both, for feasibility testing of potential solutions and adaptation to a program. Equally important, however, is that agencies such as LEAA are seriously interested in furthering innovative progress in selected areas.

Fireman's Life Support System. The problem of the Fireman's Life Support System (FLSS) originated in the need of municipal fire departments for a reliably functioning breathing device for use during fires. Following a request by the Boston Fire Department to NASA in 1969, IITRI performed a study of various aerospace technological developments which, when put together, form an efficient life support system. The basic component, the oxygen source, derived from a Portable Environmental Control System developed for the Apollo Program, uses a potassium sodium chlorate candle as the source of high-purity oxygen. Another item selected for the FLSS was the face mask derived from faceplate visors used by astronauts. The faceplate uses special properties of liquid crystalline materials that change the color of reflected light in relation to temperature. The visor is temperature sensitive and non-fogging. Thus, the fireman can have a visual window to indicate temperature conditions. The harness assembly was derived from a special unit developed at Kennedy Spacecraft Center; it is used by the Pad Rescue Team for quick rescue of astronauts in cases of emergency.

It has been noted previously that a major hindrance to completing a transfer of items of technology is lack of funds for feasibility testing. In the case of the municipal fire departments, no single agency in government or elsewhere takes the interests of firemen to heart, as did the LEAA in the case of law enforcement. The National Bureau of Standards (NBS) has only recently been assigned the responsibility of establishing the Office of Fire Research and Safety.

Lack of information on breathing requirements during actual fires has been another element to delayed technology transfer. Several studies underway on this subject will, when completed in the near future, hopefully provide valuable data related to weight and volume requirements for the oxygen-producing system.

The IITRI TATeam participated in an informal seminar on life support systems in September, 1970, along with other participants that included scientists from NASA Field Centers, the Bureau of Mines (the agency responsible for certifying breathing devices), and the National Bureau of Standards (NBS). Considerable interest was shown in the life support system resulting in two possible avenues toward successful conclusion of this problem. The NASA Manned Spaceflight Center has expressed a willingness to perform the necessary prototype development work, and plans are currently being implemented, in close coordination with NBS and other interested agencies, to complete this prototype development work. Sources of funding are being considered for a program of constructing and field testing of multiple units. Successful transfer of this aerospace technology will constitute the first major advance in fire department breathing devices in 25 years.

Measurement of Airflow Velocities in Coal Mine Passages. The hazards connected with a coal miner or with working in a coal mine scarcely require a reminder. However, as in many other areas, only a major tragedy stirs the population to action to prevent catastrophes. A recent event was the disaster in 1968 at Mannington, West Virginia, which resulted in legislation aimed at reducing mine fatalities and establishing new standards for safety and working conditions. An adequate flow of air through the mine is an important factor that contributes to safety and good working conditions; fresh air for breathing and adequate airflow to prevent accumulations of highly explosive and poisonous methane gas are imperative. Since uniform airflow throughout a mine is virtually impossible, detailed knowledge of the existing airflow is extremely important.

The Bureau of Mines, a Problem Originator, pointed out that a device to measure the air movement is a basic need. Ordinary airflow measuring instruments are not sensitive enough in order to detect the low velocity windflow in mines.

A NASA Electronics Research Center scientist suggested that a fluidic air sensor, capable of measuring speeds of less than 10 feet per minute, would be useful in solving the low velocity windflow problem. Information on this sensor conveyed to the Bureau of Mines was received with enthusiasm. The instrument was developed by the Bowles Fluidics Corp. for Electronics Research Center (ERC) to be used as an air speed indicator on vertical/shortfield take-off and

landing (V/STOL) aircraft. After further study, the IITRI TATeam prepared and submitted a report to the Bureau of Mines describing the capability of the NASA instrument as adaptable to mines application. The report, "Measurement of Airflow Velocities in Coal Mine Passages," was received favorably. The Bureau of Mines indicated in September that they wished to test the instrument in their wind tunnel, and develop a portable model of the unit which they would evaluate in the laboratory and in an underground mine. This work is now in progress.

The preliminary transfer of technology to the Bureau of Mines represents a different progression from that described in previous examples. In this case the Bureau of Mines had the funds, facilities, and interest to perform the necessary adaptive engineering and evaluative testing.

The NASA-sponsored fluidic device has also received attention from another source independent of any TATeam effort. The U.S. Navy recognized the usefulness of the airflow measuring instrument and has modified it to measure both wind speed and direction for a number of aircraft and meteorological applications.

Dust Monitoring in Coal Mines. The airflow sensor just discussed indicates the need for developing instruments specifically to improve working conditions and safety in mines. In both areas, coal dust and its concentrations within the mine are important factors. Coal dust is an element that can initiate mine explosions and aid in propagating methane gas explosions over a wide area. Coal dust is also a major cause of "black lung" disease. Recent standards established for mine operations require reduction of the level of coal dust within the mine. To meet the standards, the reduction effort will require effective instruments with capacities that instruments in current use are not capable of fulfilling. This situation established a Bureau of Mines need for a sensor or particle analyzer to function as a dust monitor.

In a computer literature search for information related to the Bureau of Mines requirement, the IITRI TATeam located references to a particle analyzer developed for the NASA Electronics Research Center. The instrument, a portable multichannel aerosol particle analyzer, was developed for use in the Apollo Command Module. It is lightweight, compact, rugged enough to withstand takeoff and re-entry of the space module, self-powered, and can operate over a wide temperature range. The instrument is also designed to count five particle size ranges between the limits of 0.5 and 10 microns. In the configuration for use in the space capsule, the instrument was in the one-of-a-kind category and expensive.

In cooperation with the NASA Office of Advanced Research & Technology, the instrument was demonstrated to Bureau of Mines officials and scientists. There were mixed initial reactions resulting from the fact that the instrument, as designed for NASA use, could not yield gravimetric readings nor could it distinguish rock dust from coal dust.

The early demonstrations of the instrument, however, resulted in an advantage in that the need for dust monitoring technology was brought to the

attention of NASA scientists, and this provided impetus toward development of the particular technology. A special project was initiated, coordinated by the Office of Advanced Research & Technology (OART), to:

a. Test the correlation of the NASA ERC particle monitor to standard mine sampling techniques for coal dust. The Harvard School of Public Health cooperated in this project.

b. Investigate the possibility of cost reduction and explosion-proofing the instrument

c. Interface with Stanford Research Institute (SRI) scientists conducting a study of dust monitoring methods for the Bureau of Mines.

The aerosol particle analyzer was accepted completely in principle by the Bureau of Mines in August, 1970. NASA and the IITRI TATeam arranged to transfer one copy of the Apollo Model, one breadboard model of an advanced version, and detailed engineering drawings to the Bureau of Mines, which the Bureau plans to use in laboratory experiments. If the instrument performs satisfactorily in the laboratory, the Bureau will contract a commercial firm to build a model adapted for use in the mine.

The potential market that will develop for this instrument is an interesting aspect of the problem. The Bureau of Mines estimates a need of between 200 and 300 instruments for use by its inspectors. The cost of the instrument NASA scientists estimate can be reduced from its original high cost of $40,000 for the model to something on the order of $5,000 each in mass production.

The aerosol particle analyzer example demonstrates a Problem Originator's willingness and capability to perform adaptive engineering to arrive at a solution to his problem. The literature search, as another means toward locating a problem solution, is also demonstrated.

Reservoir Water Column Density Measurement. Reservoir pollution that may result from a stratification process is a cause of water pollution not generally known to the public. Stratification is dependent on water depth, temperature, and chloride concentration, and becomes a problem when water in the lower section of the reservoir becomes anaerobic, or oxygen-depleted. All water in the reservoir is then not potable, and may result in water supply shortages. Part of the effort directed toward alleviating this problem requires a means of determining the stratification within the reservoir. Early detection of stratification will enable pollution specialists to take remedial action. This dictates a need for measuring the water density throughout a "column" of water in the reservoir.

The IITRI TATeam was able to locate a tentative solution rapidly --- a means to measure water density. The device is a fluid density analyzer, developed by a NASA contractor, which works according to the theory of measuring the buoyant force of a specific volume of displaced fluid to determine its density.

The instrument is insensitive to motion, light-weight, portable, and can be used on a sounding line at various depths. Information on the contractor-developed instrument was presented to the Federal Water Quality Administration (FWQA), the Problem Originator, in May. The FWQA evaluated the information and in June agreed that the instrument appeared to have merit as a feasible solution to the water-density measuring problem.

The next step was to obtain a working model for evaluation. This represented a departure from previous approaches. The TATeam had identified a potential solution; a NASA contractor developed the instrument that was considered the potential solution; and a Government agency, the FWQA (The Robert S. Kerr Water Research Center) had agreed that the instrument could be a potential solution to their problem. The Water Research Center, unfortunately, was operating under constraints which did not permit their direct evaluation and adaptation of an instrument furnished by the contractor through the TATeam. The constraints made it necessary for the contractor to submit an unsoliticited proposal to the FWQA in Washington to redevelop the instrument for a specific purpose. The proposal was prepared by the contractor in September.

Similar problems exist in other Government and quasi-Government agencies, including the Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers. The contractor for the water-density measuring device intends to contact such agencies, to investigate possible needs for the instrument.

A Methane Monitor for Coal Mines Another problem facing the Bureau of Mines is associated with methane gas accumulations. Methane is particularly dangerous in mines where it may be ignited by frictional or electric sparks. To lessen the danger of explosion, the mine must be well ventilated in order to keep the concentration of methane below the lower explosion limit of the gas (5 percent). When methane concentration exceeds 1.5 percent a mine is considered unsafe, so it is obviously important to accurately determine the methane concentration.

The IITRI TATeam located three potential means of determining methane concentration:

> An indium-sesquioxide sensor developed by a NASA contractor as a hydrogen detector. The principle of operation is based on the change in electrical resistance of the thin-film oxide when exposed to various concentrations of the gas. The device will respond to hydrocarbons including methane and thus is a potential solution to the methane concentration problem as well as to some air pollution problems.
>
> A W-value sensor, developed by a NASA consultant, which is a low-priced chromatograph useful in monitoring methane.
>
> A miniature mass spectrometer developed for NASA's Voyager program.

The three possible solutions were presented to Bureau of Mines scientists for tentative evaluation in September. The miniature mass spectrometer drew the most interest, but no decision has been made on which device to consider further. A breadboard unit of the miniature mass spectrometer at the Langley Research Center detects up to 50 mass units but the scan range can be extended. The contractor advised the TATeam that the instrument has been modified so that it will now distinguish between carbon monoxide and nitrogen, both of which have the same mass number. This capability was achieved by incorporation of a miniaturized gas chromatograph, which is described in NASA Tech Brief 70-10402.

The miniature mass spectrometer shows possibilities for a number of useful mine applications; this will be pointed out in the next discussion of a preliminary transfer. As a methane monitor, the spectrometer may be too costly to be adapted as a personal, portable instrument to be used by a number of people at the mine working "face". Should this be so, one of the other devices might be better utilized. The TATeam is now waiting for the Bureau of Mines to decide on a device. When a decision is made, sufficient information will be given the Bureau so that design specifications can be set prior to requesting bids from a contractor.

Mass Spectrometer. In the discussion of the methane monitor problem, it was noted that a miniature mass spectrometer could have a number of applications in a mine, for example, as an air monitor in ventilation ducts, as a detector for a number of harmful gases, and as a check for oxygen deficiency. The TATeam suggests that several instruments could be located at strategic positions in a mine, and be integrated into a telemetering system to provide continuous environmental data to a central monitoring system. In this way the requirement and use would be quite different from that described in the preceding problem. The miniature mass spectrometer appears adequate as a possible solution to the methane detector problem. In October the TATeam presented detailed technical information relating to the miniaturized mass spectrometer to the Bureau of Mines, which it will use in preparing specifications for an instrument to meet their needs prior to letting a contract.

Communications Link: Automatic Trouble Shooting. Locating a trouble spot in computer communication links between computer terminal facilities is a problem that was presented to the IITRI TATeam by the Maryland State Police. Current methods of operation require manual tracing to locate faults, resulting in excessive outage or downtime. Loss of the computer is expensive and puts the system out of order.

During a visit to the Kennedy Space Center the TATeam was shown the computer facility that automatically tests the entire Apollo launch system. The facility is connected to each test site by telephone cables. The line quality system monitors the communications channels for proper circuit parameters and energizes an alarm if these parameters are not within allowable limits. The system assures the availability and quality of a communications channel whether it is in use or idle. It also determines when the transmission quality of an idle channel has been interrupeted or deteriorated below usable standards. Also, channel quality during circuit use is monitored.

The computer facility is NASA technology that has advantages over commercially available monitoring devices. The NASA equipment is capable of monitoring voice and high-speed data channels; high priority voice channels that do not carry traffic most of the time must be operational and immediately available.

A Technical Support Package (detailed technical information) for the line quality monitor was presented to the Maryland State Police, who affirmed that the system appeared to meet their needs. The next step in the transfer process will be when the police department representatives accompany the IITRI TATeam to Kennedy Space Center to see the equipment in operation. Meanwhile, the LEAA plans to fund and set up a pilot project to demonstrate the equipment.

The equipment used at Kennedy Space Center cost about $30,000. However, volume production, which may result if the LEAA-sponsored tests are successful, would lower the cost. A large market for the equipment for use by police is anticipated. Other communications-oriented users are another potential market.

Non-Destructive Measurement of the Thickness of Portland Cement Concrete Pavement. State highway departments have need for a method to determine the thickness of concrete pavement. A road crew ordinarily blocks off a portion of the highway, then uses special coring equipment to make a number of core holes in the roadway. The retrieved core, when analyzed by the engineer, can provide various information relative to the construction of, and wear and tear on, the road surface. However, this is a destructive test which is time-consuming and costly for the state, as well as annoying for the motoring public. A nondestructive method of testing is needed.

The California Division of Highways (CDH), while conferring with the Stanford Research Institute (SRI) Transportation TATeam, asked that a study of a nondestructive method of determining the thickness of pavement be made to find applications for NASA technology to assist the CDH.

SRI published the Problem Statement in their Monthly Report which is circulated to all NASA Field Centers. This is part of the regular routine of the TATeam program. Thus the Problem Statement came to the attention of NASA scientists at the Marshall Space Flight Center. Contact was made between the NASA scientists and the TATeam, revealing that a NASA-developed device could measure pavement thickness nondestructively. In fact, a working model was being constructed for the Pennsylvania Highway Department (PHD) at that time.

The PHD had learned of the NASA device through two NASA Tech Briefs. Tech Brief 68-10183, "Detection and Location of Metallic Objects Imbedded in Non-Metallic Structures," described a small battery-operated eddy current proximity-measuring device that would detect objects the size of a dime at distances up to 1 foot. The device was used by NASA to measure the thickness of spray-on foam insulation on the NASA Saturn S-2 rocket stage. The second brief, Tech Brief 70-10107, "Detection and Location of Metal Fragments in the Human Body," presents a modified version of the eddy current device which can be used for on-site location of ferrous or non-ferrous metal fragments accidentally introduced into the human body.

It was as part of another National Cooperative Highway Research Program study, "Evaluating Procedures for Determining Concrete Pavement Thickness and Reinforcement Position," that the PHD learned of these Tech Briefs. The NASA Tech Briefs came to their attention during investigation of possible methods of determining pavement thickness. Discussions between the PHD and the NASA scientists led to the NASA-developed instrument designed specifically to be used in measuring pavement thickness. The device is basically a metal detector, and detects a sheet of metal foil laid on the base course before paving. The foil can be of any expensive metal, 12 to 18 inches square, with a minimum thickness of 0.02 mm. The instrument can be turned to discriminate between the reinforcing rods and the base plate. In order to test this instrument, as well as a number of other instruments showing feasibility for nondestructive measurement of pavement thickness, the PHD specially prepared a section of their test track. Foil was installed as part of the test preparations. A test was conducted in late August and early September on the NASA instrument and test results are now being analyzed. If successful use of this instrument in this particular application is indicated, it will be included later in a test covering a six-state area.

A favorable feature of the metal detector versus other proposed devices is its cost. The NASA designers of the device estimated its commercial cost at about $500, while most other instruments being considered in the study cost in the $3,000-$4,000 range. The potential public market for the instrument is estimated at 20 instruments per state. Cost savings to the states would be significant.

Miniaturized Mass Spectrometer. In the field of marine sciences, recent research efforts have established a need for a miniaturized mass spectrometer. Equipment currently used is the immobile laboratory type which necessitates transportation of phytoplankton or other marine organisms from the field to the laboratory. The adverse effects of the transit interval are not known, thus appropriate allowance for them cannot be made in the experimental endeavors. If placed aboard a research vessel, a very small mass spectrometer would eliminate this transit time and allow better simulation of the actual environment. It would be more desirable placed in a habitat on the ocean floor. Researchers at the University of Miami found significant differences between dissolved gas concentrations analyzed in an ocean floor habitat and those obtained in a sample analyzed on board ship or at the home laboratory. The major use of the miniaturized mass spectrometer will be to gain understanding of the reproduction of algae, and of marine animals, which serve as lower links in the food chains. This is essential to better management and utilization of marine resources and marine ecology. It was designed for use aboard high-performance aircraft, and is deemed adaptable to marine life usage. This instrument is small, lightweight (less than 30 pounds), and is capable of continuously monitoring 12 different gases.

Before application of the small spectrometer to marine science, modifications must be made to the ion pump and electrometers. The Problem Originator, the University of Miami School of Marine and Atmospheric Sciences, has indicated interest in funding the engineering effort required for redesign, and for an experimental program in use of the instrument.

## POTENTIAL TRANSFERS ACHIEVED

There were 13 problems that reached potential transfer status.

Wind Tunnel Design Criteria. The National Air Pollution Control Administration (NAPCA) plans to construct an on-site, low-speed wind tunnel to determine the behavior of particulates in stack gases. This is a part of their research effort and facility. The tunnel must permit measurement of particulates at flow rates between 10 and 120 ft. sec. Design criteria were needed to incorporate the best combined design factors for optimum configuration, wall effects, and size. Since NASA had considerable expertise in wind tunnel engineering, it was judicious that NAPCA presented this problem to the TATeam. Several useful documents were located by the literature search, and a Langley Research Center scientist provided consultation to NAPCA. Sufficient information obtained by NAPCA enabled them to begin preparation of specifications to issue to potential contractors for construction of the tunnel.

Reservoir Water Column Density Measurement. A potential transfer claim on water density measurement reached the preliminary transfer stage. It is discussed in the previous section on transfers. The claim resulted essentially from IITRI TATeam literature searches.

Ultrasonic Torque Wrench. Rivets are no longer used in building construction; bolts are now the most common fastening device. For the safety of the building, it is highly important to insure that the bolts are tightened properly so that the load on the beam is effectively transferred. To achieve this, elaborate precautions are taken. Measurements are often made to determine the torque on the bolts in the building. With current methods that have been developed from mechanical principles, it has been found that up to 75 percent of the torque measured can actually represent friction rather than beam stress. A device using ultrasonic principles to measure torque was developed at Marshall Space Flight Center.

A commercial firm obtained a license to fabricate copies of the ultrasonic torque wrench developed at Marshall Space Flight Center. However, it had not been able to see a prototype, let alone test one. The TATeam was able to make arrangements for a demonstration and test evaluation. If the evaluation is successful, the commercial firm is equipped to manufacture and market this aerospace device in a model adaptable to the building industry.

A Low Cost, Reliable Fire Warning System for Use in Residential Dwellings. Early smoke detection was one of the top priority technological requirements of the Operation Breakthrough program of HUD. The requirement was underscored in HUD's Guide Criteria for Operation Breakthrough, requiring that smoke detection and alarm systems be installed in multilevel dwellings under the program's sponsorship. Approximately 12,000 lives are lost each year in home fires. When most fires begin, small amounts of smoke are generated.

Smoke detection systems are commercially available at a cost of $50 to $150 per room, which is too high for the majority of home builders. Alternate

technological approaches for a solution to this problem were developed by the TATeam in conjunction with members of the Massachusetts Institute of Technology (MIT) Urban Systems Laboratory. Approaches included infrared, ultrasonic and ultraviolet detection methods. A new polymeric material, polyphenlyacetylene, whose electrical properties change when it absorbs gases or particulates, was identified. When used as a coating on a field effect transistor, the polymer can measure the changing electrical properties; it also acts as an effective contaminant detection device. Originally developed for use on the Voyager mission, the device operates on the principles of olfactory perception. McDonnell Douglas Corporation, inventers of the detection device, still have a prototype of the device although it is not in working order. The TATeam is currently arranging for its refurbishment so that preliminary tests can be made.

The ultimate price for the sensor, it appears, will be about $1-$10. The installed cost has not yet been estimated but is expected to be significantly lower than the current, lowest priced unit on the market. A low-cost device would be significant in that a great many homeowners could afford a detection system, and better protection would be available generally.

Fire Retardant Coatings. NASA, as a result of its interest in heat ablation, has developed a new, highly stable class of intumescent materials which can be formulated as mastics by the addition of short fibers of glass. A mastic designated Ames Mastic 313 was developed by the Chemical Projects Research Office, Ames Research Center (ARC) as a protective coating for bombs. Transfer efforts for this material began with identification of the need for improved mastics by the New York State Urban Development Corporation (UDC). This group is currently supervising the construction of 43,000 housing units.

Because steel loses its structural strength early in a fire (60 percent loss in strength at 950°F compared to 70°F), some building codes require compensating protection. Michigan, for example, requires 1 hour protection for structural steel in school buildings; New Jersey requires 30 minutes. Mastics (high viscosity, pasty materials) are generally applied with spray equipment to a thickness of the order of 0.5 inches. Cement is mastic material commonly used. Intumescent materials that swell, when heat is applied, and form an insulating char layer are also used as mastics.

The potential solution to this problem, the ARC-developed Ames Mastic 313, was located through contact between the TATeam and ARC on the general subject of intumescent coatings, other than mastics. A sample of the mastic has been prepared and arrangements are being made with UDC for testing of the material on actual steel plates in accordance with the relevant UDC tests. The resulting test information will enable UDC to evaluate utility of this material for use in their program. If the material is utilizable, it would be a significant step. Not only would large numbers of units be immediately protected, but also a precedent would be set for use of this material in many buildings throughout the country.

A second area of fire-retardant coatings comprises intumescent paints. In order to fireproof its space vehicles, NASA has developed a new class of

intumescent paints that eleminates undersirable properties. Such paints had been available for some time, but lacked desirable properties other than fire protection. For example, these materials tend to be deactivated in high humidity conditions; do not have good color stability; have poor mechanical properties; and cannot accept pigmentation.

The problem of fire protection was given top priority by the Department of Housing and Urban Development (HUD). Both organizations were aware of the commercial intumescent paints but, because of the negative features, were not making use of the materials. The TATeam has arranged with the National Association for Home Builders (NAHB) for a first opportunity to test the utility of the new NASA paints in connection with housing. NAHB has need to protect certain plastic parts from accidental fires. The test materials are being coated by NASA in preparation of tests at the NAHB in the near future and, if satisfactory, a wide new range of application would open for a NASA technology.

Sewage Processor for Highway Rest Stops. Most rest stops along major interstate highways, which provide a place to rest and eat and a comfort station, are located in rural areas far from a necessary sewage system, although electricity and gas are often available. Means of handling sewage from the comfort station must be developed to avoid damaging the surrounding ecology. This generic problem is common to all states. It was originally presented to the TATeam by the Montana Highway Department.

There are two methods currently for sewage disposal at rural rest stops. Local health regulations for construction and ground permeability may rule out septic tanks or leeching fields. The second method uses holding tanks and chemicals requiring frequent servicing and transporting of sewage to a distant central processor. This is costly and there is objectionable odor.

A potential solution which overcomes the drawbacks of existing methods is the "Hydro-John" waste management system, being developed for NASA, the U.S. Air Force, and the Atomic Energy Commission by the General Electric Space Division. It was conceived as a waste dispoal system for manned spacecraft voyages of long duration--on the order of 180 days. The contractor and the NASA Field Center that has primary interest are currently investigating the technical and administrative aspects of "down-to-earth" adaptation of this spacecraft system. A second application might be a modified adaptation to a wheel chair for use by retarded children incapable of normal control of body waste functions.

The initial results of this preliminary transfer have saved the State of Montana $15,000 in research funds. This amount had been allocated to the first phase of a research program before the TATeam made information available to the Montana Highway Department. The first phase of the research program can now be eliminated.

Measuring Reflection Spectra of Very Small Evidence Samples. The California Criminal Identification and Investigation Bureau (CII) presented to the SRI TATeam a problem common to all criminalistic laboratories. Essentially, it is to identify an object by analyzing a small particle of material, for example,

identifying an automobile from a small paint scraping left by an accident. The size of the paint sample may vary from one to several square centimeters. It has been practice to make a visual comparison with sets of manufacturers' standard paints supplied by means of a binocular microscope. Comparison is frequently difficult and sometimes impossible.

A NASA scientist at Goddard Space Flight Center suggested measuring the reflectance of small samples in spectrophotometers which use an integrating sphere. In place of the ususal sample, a plate is inserted carrying a standard microscope objective at the focal point; the microscope objective conveys the illuminating beam to the sample and returns the reflected light to the integrating sphere.

This solution has been accepted by the CII. Paint samples obtained from various crime laboratories were given to the NASA scientist for testing. Feasibility tests were successfully concluded in November 1970. Additional adaptive engineering will be required to develop a prototype piece of hardware.

Time and money can be saved by using the proposed instrument. For example, if 250 court cases can be eliminated where the accused plead guilty, because the police have unquestionable physical evidence supplied by this equipment, the savings may be as much as $1,000,000 in laboratory, investigative, legal, and court costs.

Simple Methods of Analysis for Metals and Metal Products. A problem common to criminalistic laboratories is inability to quickly identify the metallic composition of objects to determine their source. For example, obliterated serial number plates, tool marks, and bomb fragments must be identified to determine who the manufacturer is. Spectrographic techniques are useful but are not available in many laboratories.

Langley Research Center scientists developed a wet chemical quality assurance technique to assure quality fabrication of hardware and maximum safety to personnel in various NASA programs. The technique is relatively nondestructive; it consumes or affects an amount of material equivalent to that removed by a smooth file or cleaning with an abrasive. The technique uses standard chemicals and is rapid, taking less than 1 hour.

The Santa Clara County (California) Criminalistics Laboratory has carefully evaluated the publications describing this technique (Tech Brief 70-10520 and Technical Support Package TSP70-10520) and has stated tentatively that the technology appears to satisfy their needs. Before a final decision can be made, standard reference metals must be established as checks.

Fingerprint Image Enhancement. Fingerprint records generated at field stations in New York are transmitted to the central repository, the New York State Identification and Intelligence System (NYSIIS), by facsimile equipment. The NYSIIS estimates that more than 60,000 prints are so handled each year, and that about 40 percent of the prints become illegible, smudged, or distorted during this 14-minute transmission on the facsimile circuit. It would be advantageous to law enforcement authorities if these poor quality prints could be restored to a readable state.

While investigating this problem the IITRI TATeam was made aware of a computer processing method that could be applied to enhancing the details in photographs. this method, developed by the Jet Propulsion Laboratory, has been used to enhance the detail of photographs taken during space probes of the Moon and other planets. It has proved applicable to other problems, such as the enhancement of medical X-ray photographs. It appeared reasonable that this method would be applicable to sharpening distorted facsimile-transmitted fingerprints.

The potential solution has been presented to and accepted by the NYSIIS as a possible solution to the problem. Cards containing meaningless fingerprints have been made available to the JPL for processing. If the legibility of the fingerprints is successfully restored, efforts will be made to adapt the method to the NYSIIS system.

The benefits from solving this problem are not limited to restoring the legibility of unreadable or distorted fingerprints. Since 40 percent of the annual volume of transmitted fingerprints must be retransmitted, such a solution will eliminate almost 6,000 hours of facsimile machine and operator time.

Metal Detector. An SRI TATeam problem closely tied to current events is on "Metal Detectors". An efficient system for detecting and locating metal objects, particularly guns, is obviously required for a multitude of uses. In air transportation, a primary need has been established for the detection of certain metallic objects prior to passengers boarding airplanes. In a California courtroom, recent events show that a detection system may be necessary for use on persons enteringthe courtroom.

A metal detection system developed by the Ames Research Center (ARC) can search people inconspicuously when they enter areas where metallic objects are prohibited. The detection is accomplished by a phase-sensitive (polarity) detector sensitive to both ferrous and nonferrous metallic objects. The signal voltage resulting from disturbance of an electromagnetic field within the volume of the sensitive area is compared with a reference voltage for polarity information and thus identifies the material. Output amplitude and polarity indicate the approximate size and type of metal, respectively. The system is insensitive to metallic objects below a specific size and its output is independent of the speed with which an object moves past the detector. The output may be signalled by lights, by an aural alarm, or by a chart recorder.

This system has been successfully demonstrated to representatives of San Mateo County (California). County authorities have indicated an interest in installing the device in a county courtroom for a 6-month test period. The SRI TATeam, ARC scientists and county personnel are continuing this cooperative venture.

Continuous Measurement of the Particulate Background and Source of Atmospheric Particulates. A device with a potential of measuring the mass of airborne particulates on a real time basis was developed for the NASA Marshall Space Flight Center for the Apollo Telescope Mission. It measures particulate

mass using a quartz crystal microbalance. The change in mass caused by impact of particulate matter on the crystal surface changes the resonant frequency of the oscillating crystal. The change can be measured by comparison with the resonant frequency of a reference crystal. A silicone adhesive film insures that particulates stick to the crystal surface on impact. This instrument can measure particulate mass in real time, thus may serve to determine the volatile content of aerosols. It will be demonstrated to the Bay Area (San Francisco) Air Pollution Control District, having been located by the SRI TATeam in response to a circulated problem statement.

Extendable Retractable Boom. A search for a device to actuate automatic garage doors with increased reliability and at reduced cost has located a potential solution which has been accepted by the Problem Originator. Uses include homes, fire stations, freight depots, and other municipal buildings. Several NASA-developed extendable/retractable booms were located by the ABT TATeam through literature searches, one of which was a circular cross section type developed for NASA by Melpar, Inc. Another was a triangular cross section type developed but no prototype was built at the Jet Propulsion Laboratory and described in Tech Brief 65-10101. This is the device currently under consideration by the Problem Originator, who is interested in developing a prototype for further evaluation.

Measurement of the Osmo-Regulation of Blue Crabs. Since the blue crab is important as a commercial source of food it is important that we understand the effects of pollution on the crab. A means of obtaining an understanding would be to monitor the adjustment of the internal environment of the crab as a function of external environmental changes. This can be accomplished to some extent by monitoring the conductivity of the circulating nutritive fluid of the crab.

The present approach to this problem has been to sacrifice the crab to get enough fluid to use standard laboratory procedures for making conductivity measurements. One measurement requires one crab. Thus a large number of crabs must be used to obtain data with reasonable confidence limits.

A system designed by researchers at the NASA Langley Research Center will eliminate the need for large numbers of crabs and will permit obtaining more than one measurement per crab. This system consists of a microminiaturized conductivity probe, power supply, signal conditioning electronics, and a telemetry transmitter. The entire package weighs 2-3 ounces and is one square inch in size. An important feature is the ability of the system to transmit through several feet of salt water.

A breadboard model has been demonstrated to the Problem Originator who is now evaluating the results. Successful application of this system will enable the Problem Originator to generate a greater quantity of realistic physiological data over a shorter period of time using a smaller sample size than has been possible in the past. The results of this research would be applicable to development of meaningful regulations for allowable pollution levels in estuarine waters.

OTHER TATEAM ACTIVITIES

The BAT/TAT Conference. A joint BAT/TAT Conference was held late in June with representatives attending from each team, NASA/TUD, the NASA Regional Dissemination Centers (RDC), and George Washington University (GWU). The goals of this Conference were:

a. Establish a consensus of the role the team is to play in interactions with the Problem Originator and the solution source.

b. Restate the program goals in terms of program visibility, relationship to national goals, and the operational goal of hard transfers.

c. Develop an understanding of the program's requirements in terms of applications engineering and steps to be taken to secure NASA assistance.

d. Develop an understanding of what constitutes a potential transfer and the steps necessary to get to the transfer stage.

e. Develop an understanding of what a transfer is and how a transfer may differ from other forms of technology movement across lines. Diffusion and scientific and technical information exchanges are examples of other forms. Restate the requirements for documentation.

f. Understand the purpose for a search.

g. Understand the requirement for operationally valid acceptance criteria, a clear and concise statement of the problem, and an understanding of the specific technological requirements.

h. Discussion of the program goals and problem-acceptance criteria in terms of the place of the team and the RDC in information diffusion.

The conference was successful in terms of the goals outlined. A detailed report was prepared by GWU covering the material discussed and the directional implications of the conference. It was given to all attendees by NASA/TUD.

The International City Managers Association (ICMA)/NASA Conference. The ICMA and NASA/TUD entered into a joint program in July to utilize NASA technology in developing solutions to pressing urban problems. The initial program was planned as a joint effort in which city representatives would develop preliminary statements of their problems. A panel of city representatives were to evaluate the problem statements and select problems for NASA consideration. When a potential solution was presented by NASA, the panel would evaluate the solution, and return it to one or more cities for further

evaluation and possible adaptation to their problem. An overall coordinator for the city portion of effort would be selected by and work in the ICMA headquarters. The NASA TATeams, particularly the ABT TATeam, would play an important role in the NASA effort.

Before initiating the program, it was evident that city personnel had to become familiar with NASA and with the methodology used in the NASA TATeam program. To accomplish this, a conference was held at the Kennedy Space Center (KSC), October 22-23, with the KSC Technology Utilization Office (TUD) acting as host. The conference was successful, and helped toward attaining conference goals. Much of the preliminary planning and on-scene efforts that made the conference successful can be attributed to the ABT TATeam with assistance from TUD and GWU. Nearly 100 city managers (ICMA) and their technologically oriented personnel attended, representing a total population of over 17 million.

The main purpose of the meeting was to introduce ICMA people to the potential of NASA-generated technology and to describe a means of assessing that technology in erms of requirements. The conference included a VIP tour of the KSC facilities, followed by two days of lectures, question and answer sessions, and problem solving seminars. The overall program goals were to:

a. Develop an active experimental program to identify and apply aerospace technology relevant to urban problems.

b. Improve the policies, strategies, and methodologies of technology transfer into the urban environment.

c. Assess program contributions, impact, and effectiveness in helping cities meet their developing needs for technology.

The ABT TATeam developed, as a follow-up, a procedural phased chart to depict the various steps in the ICMA/NASA technology transfer effort. The chart is shown in Figure 3. A verbatim report of the conference is being prepared for TUD by GWU.

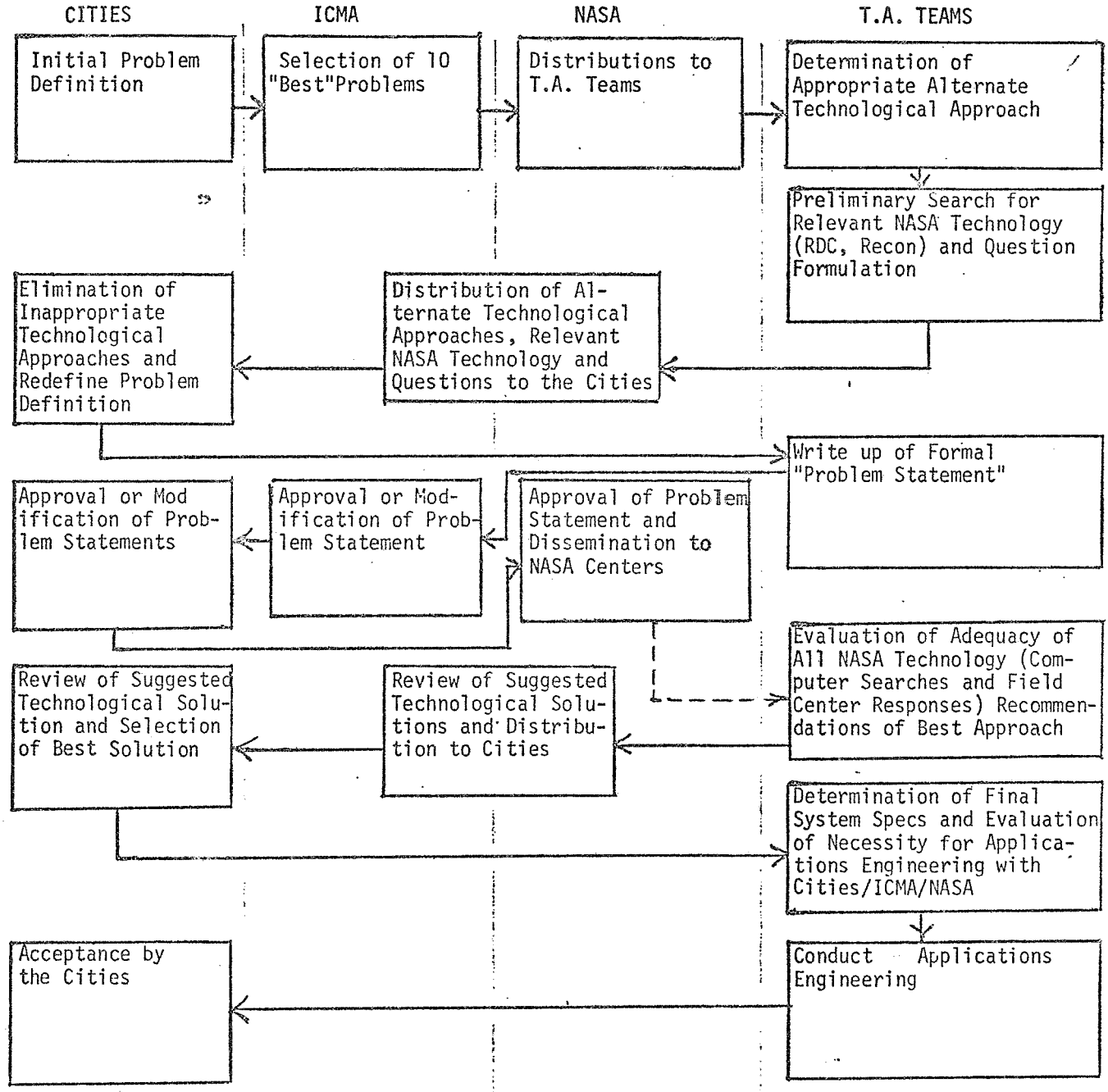
The conference participants commented generally that most city government people were interested in the same areas that the NASA TATeams are working in at this time. City interest is essentially in water pollution, solid waste management, mass transportation, urban renewal and law enforcement.

Urban Development Applications Team; Federal/State Agency Cooperative Efforts. Two significant activities are highlighted in the urban development effort.

a. The ABT TATeam and the Department of Housing and Urban Development (HUD) have agreed informally that it would be beneficial to both if one of the TATeam's members would work part time directly with HUD's Office of Science and Technology. The designated team member

FIGURE 3

OUTLINE OF THE TECHNOLOGY TRANSFER FROM NASA TO THE CITIES



will be located at HUD for the specific purpose of facilitating problem identification and providing rapid response. This arrangement will enable the TATeam to identify problems early with higher specificity. It will also further development of the experimental aspects of the TATeam program.

b. Closer cooperation has developed between the TATeam and the New York State Urban Development Corporation (UDC). The UDC has the major responsibility and complete and continuing authority for development of housing projects from land acquisition to final construction. With this comprehensive responsibility, the UDC can adapt innovations to projects, even when innovations may not comply with, or differ from, existing housing codes or zoning regulations. Consequently, cooperation with UDC provides a fortunate opportunity to introduce concepts which in the past might not have received consideration, regardless of merit.

NASA Technology/Urban Construction Conference. A seminar conducted by the ABT TATeam proved to be of significance. It was directed toward facilitating transfer of technology to the housing construction industry and determining the barriers to transfer. To accomplish these goals, the ABT TATeam brought together various interested industry representatives and NASA technologists, to introduce specific NASA technology by presenting a basis on which to decide on further pursuit of technology applications.

The purpose of the seminar was to determine:

a. How can NASA aerospace technology be used to help solve urban construction problems?

b. What are the major barriers to technology transfer?

c. Can small conferences and seminars break down some of these barriers and facilitate the transfer process?

Two NASA technological areas provided direction for the seminar: flat conductor cable technology, and the application of polyurethane spray foam.

Later, the seminar was evaluated as an effective means of accelerating the transfer process. The ABT TATeam has made recommendations for future seminars based on its experience. The seminar that was held and the recommendations made are recorded by the ABT Associates, Inc. in the publication, "The Application of NASA Technology to Urban Construction," of May 1970.

# SUPPORTING ACTIVITIES

## SUPPORTING ACTIVITIES

A number of activities are carried out to strengthen the overall Applications Team effort. These special studies and projects are described here briefly to help provide a well-rounded picture of the Program.

National Academy of Engineering. The NAE's Committee on the Interplay of Engineering with Biology and Medicine (CIEBM) has undertaken, through its Subcommittee on Technology and Systems Transfer (chaired by Dr. David Rutstein, Harvard Medical School) a "Study of Aerospace Technology Utilization in the Civilian Biomedical Field." This is a one-year NASA-sponsored effort designed to:

- Identify Aerospace Engineering Technology which appears relevant to specific technological requirements in the biomedical field.
- Relate the biomedical requirements to identified engineering technology in a manner so as to facilitate follow-on activities by the NASA at its option.
- Provide expert professional advice concerning initiation of specific projects identified in the preceding activities.
- Identify and recommend to NASA interfaces with mission-orientdd organizations that will contribute to furthering the goal, on a continuing basis, of transferring engineering technology to biomedicine.

After an initial familiarization period, the Subcommittee created three ad hoc Groups to focus their study efforts on the areas of cardiovascular care, pulmonary care, and remote diagnosis and treatment. The groups will develop statements of medical problems within their specialities as they pertain to the delivery of health care; the problems will be ranked on the basis of appropriate criteria. The groups will then evaluate current projects and technology within NASA and those of other agencies that could have impact on the problems delineated. Finally, they will specify which technological developments hold potential relative to problems, but that require further reengineering, then suggest to NASA specific means to begin the process of transfer. The final results of this study will further improve the focus of current Biomedical Applications Team efforts and help to identify significant new transfer opportunities of biomedical importance.

George Washington University. The Biological Sciences Communication Project (BSCP) of the G.W.U. Medical Center has been under contract with NASA's Technology Utilization Office since 1965, to provide technical and analytical assistance to the Biomedical Applications Team Program. In 1970, this project was expanded to include the Technology Applications Teams which were working with public sector agencies. The BSCP's Technology Applications Group provides

NASA with continuing general system support for the qualitative and quantitative analysis of the Application's Team Program. Detailed monthly reviews of various aspects of the technology transfer process aid in the deisgn and evolution of improved transfer systems. The BSCP supplements the problem identification task of the NAE Subcommittee by investigating and calling to the attention of NASA significant problem areas for the entire Applications Team Program. When required, the BSCP recommends to NASA appropriate interfaces with agencies or organizations capable of identifying new problems, or to further the NASA technology tranfer efforts.

W.H. Clingman and Co. Dr. Clingman and his associates have conducted two studies for NASA's Technology Utilization Office. The first study was a detailed, communication-oriented analysis of the Problem Statements prepared by the Applications Teams. This study resulted in a special publication, "Guidelines for the Preparation of Problem Statements," which defined in detail and illustrated the necessary content of Problem Statements. The Guidelines also suggested techniques for Problem Statement preparation. The second effort, "A Study of NASA Literature Search Strategies," was a three-phase study and literature search experiments. It investigated several anomalies in the Applications Team's literature searching that was conducted by the Regional Dissemination Centers. The study recommended a number of procedural innovations designed to improve the Program's ability to efficiently access the 750,000 documents in the NASA Aerospace Data Bank.

Sensory Aids Study. The Battelle Memorial Institute conducted a four-month study designed to identify current technological requirements within the area of sensory aids. These requirements, as well as relevant NASA technology and capability, were presented to NASA in a Special Report. The focus of this effort was on improved aids for the visually handicapped, which include the blind as well as the partially sighted. Several new areas of Program effort have resulted from this study. First, the Special Report was distributed to all NASA field center Technology Utilization Offices to identify relevant NASA technology and expertise which might contribute to these requirements. As a result, the Langley Research Center has begun fabrication of an improved lightweight cane. The Goddard Space Flight Center has begun to evaluate the feasibility of using a hand-held gyroscopic device to provide a reference system to permit a blind person to cross a street in a straight line. Finally, the National Institute of Neurological Diseases and Stroke has indicated a strong interest in the statements of technology requirements for the handicapped and in the NASA technology already applied or potentially applicable to their (NINDS's) problems. Relevant NASA technology is being subjected to a coordinated review by NINDS and NASA's Technology Utilization Office.

Biomedical Problems Survey. The General Research Corporation, Washington, D.C. Office, conducted a five-month study designed to identify current significant efforts in both biomedical research and clinical medicine for which technological and/or engineering contributions were needed. The study focused on those efforts which are being carried out in an interdisciplinary context, where physicians are working closely with engineers and physical scientists

toward the solution of biomedical engineering problems. Eight major areas were covered in this exploratory survey:

a. Artificial organs and assistive devices

b. Automation of clinical laboratories

c. Clinical instrumentation

d. Hospital information systems

e. Medical telecommunication

f. Intensive care patient monitoring

g. Multiphasic health testing screening

h. Prosthetics, sensory aids, and rehabilitation

The specific problem areas identified will be used to compare with current Biomedical Application Team problems, and serve as a basis to re-allocate program focus if it appears desirable.

Cyber, Inc. Cyber, an information systems firm, is deeply involved in health information systems design. Recently it undertook a five-month study to identify NASA technology pertinent to hospital needs in the areas of patient monitoring, hospital information systems, and general management techniques/systems. The final output of this study will document the identified technological requirements and relevant NASA technology in these three areas. The study results will be used to illustrate to interested administrative and medical hospital personnel the potential for use of NASA technology in their environment. It is expected that this exposure to useful technology will motivate more active acceptance of this technology in the hospital milieu.

Biomedical Applications Engineering. The University of Virginia's Division of Biomedical Engineering is participating with NASA's Office of Technology Utilization ina small-scale pilot project to modify selected aerospace technology for application to biomedical problems. The University was already cooperating with NASA under the Sustaining University Program and was also developing capabilities in an applied medical engineering program. The objectives of this project are to:

- Assess the general feasibility of adapting aerospace technology to meet the technological needs of specific biomedical problems.

- Review specific bioengineering end items requirements for biomedical needs and assess the relevant capabilities of identified aerospace technologies and the degree of adaptive engineering required to match the technologies with the requirements.

- Carry out a limited number of biomedical applications engineering projects as selected by NASA, the Biomedical Applications Teams, and the Division of Biomedical Engineering of the University of Virginia.

- Identify where appropriate, commercial/industrial capabilities which might serve to adapt aerospace technology to meet biomedical requirements.

A number of biomedical applications engineering project candidates were reviewed and several pilot projects were initiated during the first year of this effort. All of the project candidates are based on biomedical problems accepted and defined by the NASA Biomedical Applications Team Program.

The first technical project currently nearing completion is a prototype implantable rethral valve designed by an aerospace engineer in response to a specific need expressed by practicing urologists. The construction of an improved device for monitoring patient respiratory patterns is also nearing completion and two prototypes will be delivered to Problem Originators for clinical testing.

A low cost, pressure tranducer calibration system is also to be studied and constructed. This system will meet a need generated by the growing use of indwelling and external pressure transducers used for patient monitoring in both small and large hospitals. Previous devices for calibrating and checking the response of these pressure monitoring devices have been either expensive or imprecise.

Valuable experience has been gained from this pilot project. Along with specific technical end items for biomedical use, it is expected that the general experience in this area, which will be documented, will be of value in the broader context of the bioengineering community.

# CONTINUING AREAS OF PROGRAM EMPHASIS

## CONTINUING AREAS OF PROGRAM EMPHASIS

As pointed out in this report, the NASA sponsored Applications Team Program has focused on establishing systematic mechanisms to ensure a continuing and viable effort for the application of aerospace technology to a wide range of society's problems.

In order to further enhance the Program's effectiveness, the Technology Utilization Office will continue to place special emphasis in a number of methodological areas. These areas are discussed below.

### PROBLEM FOCUS AND ACCEPTANCE CRITERIA

The Biomedical and Technology Applications Teams have developed problem acceptance criteria pertinent to their particular areas of transfer efforts. Experience has shown that all of these criteria should not be applied to each problem considered for acceptance. In every case, however, the teams emphasize those factors which help ensure that the Problem Originator has the ability and resources to effectively use the technology which has been identified as a solution to his problem. This emphasis will be continued to avoid the pitfalls of providing a Problem Originator with technology which he cannot further develop or apply or of diluting Program resources by working with inappropriate Problem Originators. Thus, the teams will continue to obtain in-depth problems primarily from Problem Originators with an inhouse capability to perform required applications engineering or from those Problem Originators who have access to external agencies willing to fund this engineering phase. An example of the first case is in the are of mine safety. The Bureau of Mines performs necessary applications engineering and technical evaluation of solutions developed for their problems. The relationship of the Law Enforcement Assistance Administration (LEAA) to the many local law enforcement agencies and the willingness of LEAA to fund applications engineering serves as an example of the second case.

Additionally, the teams will continue to emphasize the acceptance of those problems which can be described as generic. In this respect the teams describe the generic problem as a major problem area consisting of many technological sub-problems. It is at the sub-problem level that technology transfers are completed. Focus on the generic problem area and the resultant transfers at the sub-problem level will lead to eventual solution of the generic problem. This generic focus is emphasized as the major means of maximizing the total public impact of the Technology Applications Team Program. Close working relationships with authoritative groups and mission agencies will continue to provide valuable guidance in this area.

### INTERACTION WITH NASA FIELD CENTERS

One of the important developments of the Program's experimental facet is the increasing awareness that communications between the teams and the

NASA Field Centers require continuous nurturing. A corresponding development is the recognition of a need for direct and personal communication between the Problem Originator and the NASA scientist or engineer who has knowledge of a potential solution. These two communication factors have led the teams to develop a more intimate relationship with both the Field Center personnel and the Problem Originators, resulting in improved Team familiarity with the aerospace technology within a particular Center. This knowledge enhances the team's ability to develop a solution to a problem earlier in the transfer process. A number of harmonious relationships have developed from this philosophy such as that of Research Center personnel experienced in the area of fire retardant paints and foams, a subsector of the fire safety generic problem area, with the teams.

The personal communication aspect of the technology transfer process will continue to be emphasized as an important element of the Applications Team Program in the future. This will help to shorten the time interval between recognition of a problem and presentation and review of a solution and will ensure the most effective use of the Applications Team resources. An additional benefit of this emphasis will be in the area of problem statement preparation: the overall quality of problem statements will be enhanced by improved knowledge of the technology availale, the personnel involved, and the Problem Originator's specific requirements.

## APPLICATIONS ENGINEERING

As discussed earlier, the task of applications engineering is necessary to effect transfers in cases where the Problem Originator lacks the capability or facilities to reengineer technology which is a potential solution to his problem. Applications engineering is not a separate or even major part of the Program, but emphasis will be placed on helping facilitate applications engineering for identified solutions with considerable impact in generic problem areas. One desirable means of applications engineering is cooperative effort between government agencies, such as between NASA and LEAA. Another source of cooperative applications engineering effort is that currently developing between NASA and the Bureau of Standards in the area of life support systems for firemen. Yet another possible applications engineering resource is NASA itself. However, it is important to note that at this stage in the Program's evolution each potential solution requiring applications engineering is treated on an ad hoc basis. Emphasis will be placed on applications engineering as required to effect high-impact technology transfers. Applications engineering is generally not attempted for low-impact problems or for technology which has not reached an acceptable level of development past the conceptual stage.

## INFORMATION SEARCH STRATEGIES

Another outgrowth of the experimental facet of the Applications Team Program is the development of a methodology for searching the NASA data bank for literature pertinent to a problem and its solution. Early in the Program the literature searches were less productive than anticipated because

the aerospace "data bank" was developed to locate specific information for aerospace use. The normal aerospace-oriented search strategies did not work well for the Applications Teams. An Applications Team is seldom able to locate aerospace technology to be applied to a non-aerospace problem by searching on the basis of technological terms remote from the aerospace field. A search strategy must therefore be developed so that technology bearing little or no direct relationship to the problem's technological discipline but which can be applied to the problem, will be located. This is often exceedingly difficult to accomplish.

During this past year emphasis was placed on developing improved search strategies using methods developed under a special study. In essence, this involves repetitive or parallel searching. First, one locates one or more applicable documents and the keywords or descriptors appended to those documents. These keywords are then used to develop a focused search strategy to locate those documents in the aerospace data bank as well as all other pertinent documents indexed under those terms. This methodology can be applied by the RDCs and is particularly effective when used in conjunction with the NASA Remote Console (RECON) information retrieval system. The emphasis placed on developing highly effective search strategies will be continued as an integral part of the Program's operational philosophy.

## PEOPLE FACTORS - INTERPERSONAL COMMUNICATIONS

Earlier, the importance of developing direct interchange between the Team personnel, the NASA Field Center scientists and engineers, and the Problem Originators was pointed out. This is one facet of the people involvement in the technology transfer Program and may be termed the "people factor." It has been recognized by the Program as well as by noted communications researchers that the direct interaction of people facilitates the interchange of technical information and provides an in-depth technological understanding of the problems. This communications route is necessary, particularly when the existing institutional or administrative mechanisms are cumbersome or inadequate. Continuing emphasis will be place on the "people factor" to help shorten the time between problem recognition and problem solution and also to provide the level of technological understanding necessary for effective implementation.

## CONCLUSION

There is a growing tendency for the public to look toward application of existing technology as a means of helping solve problems. There appears to be an increasing awareness of the fact that technology, and aerospace technology in particular, has a major role to play in meeting public needs. This represents a challenge which is directly related to the process of rational technology selection and application in which the NASA Applications Teams are involved. During the forthcoming months continuing emphasis will be placed on both experimental and operational facets of the Program in order to study the technology transfer process and to facilitate the accomplishment of transfers and documentation of their impact.

APPENDICES: ACTIONS TAKEN FOR
PROGRAM IMPROVEMENTS:
BIOMEDICAL APPLICATIONS TEAMS
PUBLIC SECTOR APPLICATIONS TEAMS

## APPENDIX A: ACTIONS TAKEN FOR PROGRAM IMPROVEMENT

## BIOMEDICAL APPLICATIONS TEAMS (BATEAM)

The Biomedical Applications Team Program is an experiment to develop and test techniques for transferring aerospace technology to the biomedical sector. The purposes of the Program are to identify aerospace technology which provide solutions to biomedical problems and to document such transfers for more widespread usage. The teams have been improving their methods in order to learn how to best direct their efforts.Their results now verify the Application Team concept as an instrument for technology transfer.

### USER MOTIVATION AND PROBLEM ACCEPTANCE

The success of the BATeam at RTI is an example of an effective transfer agent. The team's success is due to the team members' broad technical competence, their ability to establish good interpersonal communication, the types and quality of problems accepted and the problem solving methods used.

When the RTI BATeam receives a request for assistance, several team members visit the institution to explain the team's mission, function and type of assistance which the team is capable of providing. The recipient institution's responsibilities are also explained. Specific problems requiring further team effort are identified, defined, and ultimately accepted through a process of personal interaction between a team member and individual researchers and clinicians within the institution. The team member's ability to provide ready information on suitable commercial equipment and the latest techniques builds user confidence and enhances the team's image.

Many difficulties are encountered in working with program participants. Personal interaction is essential in motivating members of the medical community to utilize the program. Some researchers, considering themselves experts in a particular field, are often understandably resistant to fresh ideas which originated elsewhere. If assistance has not been sought at an early stage of problem development, work may have progressed beyond the stage where an improved technique could be optimally implemented. Had assistance been sought at an earlier stage of problem development considerable time and effort could have been saved. Proprietary considerations enter a number of cases where a researcher may have reservations about the disclosure of his innovative research effort and thus is reluctant toward having it described in the program's formalized reports. Such considerations often hamper mutual benefits to the team and the institution, but these barriers are being overcome by skilled interpersonal communications.

The RTI team has developed selective problem acceptance criteria, rather than attempting to deal with numerous problems. By limiting the number of problems under consideration it can focus effort onto developing a particular solution. Occasionally the team accepts and solves less than major problems for the purposes of winning user confidence and of gaining favorable consideration for more significant problems.

Although the two other teams, SwRI and MRI, have encountered obstacles, they have been productive. Their difficulties stem from the isolated, unrelated, and fragmented nature of the problems which they accept, and the methods with which they attack the problem. Although they have demonstrated an ability for solving well defined hardware problems, they have not, with rare exception, faired well with broader system problems. They are caught up on a cyclic numbers game which starts with each team accepting 10 to 20 new problems each month. This imposes a considerable strain on the team, as 3 or 4 people must solicit and define 10-20 problems per month from as many different problem originators, familiarize or update their knowledge of the state of the art in many narrowly defined areas, knowledgeably structure and evaluate a like number of computer literature searches, and continue to service all those problem originators whose problems originated at an earlier time. They often accept minor variations of problems which they have already solved as new problems, inflating the numbers and placing an additional strain on team resources. The effect of these policies is that a problem often receives less than thorough consideration and commercial equipment which might prove suitable is often overlooked. Rather than attacking large systems problems that are potentially time consuming and have long transfer time lag, these teams have sought and accepted many smaller problems for which piecemeal solutions are rapidly, and easily implemented. These teams must stress quality (problem significance within medical community) rather than quantity of problems.

In October the teams recognized that their backlog of active problems had grown beyond their ability to cope with them. At TUD's insistence, they inactivated a large number of problems to reduce their backlog to a manageable level. They have not, however, implemented stricter acceptance criteria, or suddenly demonstrated an improved efficiency in dealing with the problems at hand. It therefore seems likely that they will recycle and again build an impossible backlog.

Both MRI and SwRI have considerable engineering talent available to them and they are beginning to apply it to a larger percentage of their newly acquired problems. Rather than expend the large effort directed to new problem acquisition every month, it would seem advisable for these teams to temporarily moderate their rate of problem acceptance. Many problems have not progressed beyond the 'active' classification for want of a few hours of engineering time. Many of these problems do not require sophisticated, elegent solutions. Were the teams to propose solutions to some of these problems, they could produce some grateful problem originators and make an interesting contribution to various research or clinical efforts. By directing the teams' engineering abilities towards reducing the backlog rather than acquiring new problems during the next few months, the teams might benefit greatly from increased user confidence and requests for assistance on larger scale problems.

## LITERATURE SEARCHES

When a team and an investigator have formulated a mutually satisfactory definition and understanding of a problem, the BATeam performs a search of NASA's computerized data banks at one of six Regional Dissemination Centers

(RDCs). Effective use of the computerized information retrieval system presently entails many difficulties. For instance, searches on identical topics run at different RDC's frequently produce search results that are quite different. The articles are indexed by ten words from an aerospace-oriented vocabulary. The indexing words are frequently chosen by an "information retrieval expert," and seldom by the author of the article. A user wishing to retrieve an article from the data bank must hit upon the proper combination of words, that is, a partial set of the combination of index words. Often, concepts discussed in, or relevant to, the article, are not keyed into the index words. Even words in the title frequently do not appear in the index words. There is a lag of from 2 months to 2 years before a published article is incorporated into the data bank. The team member must be capable of considerable ingenuity to coax the desired information from the system: unless he searches all the possible terms and their synonyms which might relate to the topic, the computer search effort can be disappointingly unproductive. All of these difficulties seriously detract from the utility of the system. A major effort is in progress to provide a remedy to the problems of searching the data bank for solutions.

A search technique that shows promise, and apparently warrants further effort toward development, is based on an initial manual search of current indices for five to six appropriate articles. The index words used to describe the articles are then used as index words to perform a more detailed computerized search. Also, the RDCs are investigating improved search strategies and techniques. The RECON system will also facilitate improved search efforts. The need to translate medical needs into aerospace-related search terms often presents a real challenge. As teams become more adept at obtaining better search terms, quality and relevance of the searches improve.

PROBLEM STATEMENT

The teams often send Problem Statements to the various NASA field centers in hopes of gaining additional information not provided by the computer literature search. Many researchers within the field centers possess unique technical abilities and knowledge and thus often can provide valuable suggestions and information. To gain the cooperation of these researchers, the problem statements must challenge and motivate them to respond. Thus, the problem statement must explain the problem in non-disciplinary language, indicate what is needed and what is not needed, the techniques already used and found unsuitable, the value that a suitable solution might provide for health problems, and identify references for additional background information.

All teams have exhibited an improved capability for the preparation of well defined Problem Statements. These Statements are based on the Clingman Guidelines for Problem Statement Preparation and undergo several reviews prior to distribution. As a matter of fact, improved problem definitions and greater knowledge of field center personnel and areas of expertise often permit the teams to bypass use of a formal Problem Statement and go directly to appropriate NASA personnel.

## POTENTIAL TRANSFERS AND APPLICATIONS ENGINEERING

The use of many resources has enabled the teams to propose many potentially valuable solutions. However, the goal of the program is to effect transfers, not merely to propose potential solutions. Potential transfers items usually require modification or applications engineering for new adaptations, and funds for these efforts are frequently not readily available. Yet funding is not necessarily the resource always needed. Problem originators in the biomedical area seldom have access to engineers or technicians capable of implementing the proposed solutions. This creates a transfer time gap, which may be as large as several years, between the proposal of an appropriate technique and its actual utilization. It is important to reduce this time gap since many problems are "time perishable." It has been observed that problems which were selected in anticipation of a short time gap prior to implementation of transferred technology have tended to have less biomedical impact. Thus, in order to achieve a tradeoff the teams have attempted to treat both short-term problems and long-term, high impact problems. The NASA funded applications engineering efforts at the University of Virginia and within the teams have attempted to shorten the time gap for implementation of high impact transfers.

## TRANSFER DOCUMENTATION

All of the teams have attempted to provide more extensive documentation of technology transfers and potential transfers. A good example of this may be found in recent SwRI documentation efforts. Continued emphasis on this area will be provided by NASA and GWU. Such documentation is an absolute necessity for the effective diffusion of knowledge within the biomedical and instrumentation communities.

## CONCLUSION

The Biomedical Applications Team Program has succeeded in establishing systematic mechanisms to ensure a continuing and viable effort for the application of aerospace technology to a wide range of biomedical problems. The teams have established effective personal communications with a large number of medical researchers and institutions, thus providing many members of the medical community with a capable source of new advanced technology.

To better utilize the teams' limited resources, it is recommended that they focus their efforts on the acceptance of more generic problems. A generic problem is a major biomedical problem area composed of many related technological sub-problems. It is at the sub-problem level that technology transfers are effectively completed. Focus on generic problems and resultant transfers at the sub-problem level will lead to eventual solution of the high impact generic problem. This generic focus is emphasized as the major means of maximizing the total biomedical impact of the Biomedical Applications Team Program.

Applications engineering is a necessary part of the Biomedical Applications Team Program in cases where the Problem Originator lacks the capabilities or facilities to reengineer technology which is a potential solution to his problem. While applications engineering efforts should not become the major thrust of the Program, additional emphasis should be placed on implementing identified solutions with considerable potential impact in the medical communities. To shorten the time delay for implementation of high impact transfers, the teams should avail themselves of the prototype fabrication facilities available within the Research Institutes and the University of Virginia.

## APPENDIX B. ACTIONS TAKEN FOR PROGRAM IMPROVEMENT: PUBLIC SECTOR APPLICATIONS TEAMS

The reader must understand several important factors which will influence interpretation of this section's content. First, the TATeam program is not entirely an operational or institutionalized endeavor. It is an experimental program aimed at developing knowledge about public sector technology transfer so that a useful operational program can evolve. Second, in the TATeam Program the various teams operate in a number of different public sectors, each having different requirements and characteristics. In addition, these various public sectors operate under differing conditions in respect to their facilities, funding, ability to adapt potential problem solutions, and procedural methodology for participating in the Program.

### PROGRAM ACCEPTANCE

The program marketing packages prepared by each team together with team promotional efforts have produced a high degree of acceptance by the potential users of NASA technology. The degree of acceptance has been higher than expected since it is frequently true that new programs, particularly those which offer something for nothing, meet resistance from potential clients.

However, in many cases the marketing efforts lead to problems falling into one of two categories. One is a need for an instrument, or "black box," to solve the problem. The other requires information in the form of "What is the state of the art." Neither type of problem is undesirable. What could be undesirable is for a number of these two types of problems to over-balance the program. Instrumentation in itself is not bad as long as the instrumentation problems solved contribute to solving the overall, or generic, problem. Attempting to solve a number of small unrelated instrumentation problems can lead to dissipation of effort. Fortunately, the TATeams have begun to recognize this feature of the program and are taking steps to avoid such a pitfall.

### PROBLEM DEFINITION AND ACCEPTANCE

General. Determination of whether or not to accept a problem continues to require judicious decisions by the TATeams. At times, it appears necessary to accept an offered problem even though it may not measure up to the problem acceptance criteria in all aspects. In these few instances the problem is accepted to continue to have a rapport with the problem originator or his agency. In order to establish firm grounds for problem acceptance, TUD, at the June BAT/TAT Conference, decreed that there was one question that should be satisfactorily answered by the problem originator before a problem was accepted. This question is:

> "What would or could the problem originator do with the potential or actual solution once it is made available to him?"

Although acceptance criteria will vary from team to team it was felt that this one criterion must be common to all. The criteria used by the TATeams are given in Table 4. Another aspect of the problem acceptance area is the generic versus the sub-problem. It would be most desirable to determine the high impact generic problem area and then concentrate on the major sub-problems. Technology transfers may occur at the sub-problem level but ultimately a generic impact will result. Recognition of this view is typified by IITRI's remark that "...in some cases one can obtain a large economic benefit by combining the solutions for discrete problems into a larger system capable of impacting on what some have referred to as a generic problem."

A further indication that this view is prevalent is the statement by ABT in their Quarterly Report No. 3 that "...a number of small impacts in the same generic area, can, together, contribute significantly to the solution of key urban problems." A partial result of the recognition of this aspect of technology transfer is the recent ABT decision to concentrate their efforts on the generic area of life safety in urban housing.

The ABT Methodology. The ABT TATeam initially developed a philosophy for problem acceptance that differed to some degree from that used by other teams. Specifically, ABT attempted to match, at a broad level, urban problem areas with technology areas and market areas. The result was to bring together a problem, a technology, and someone to adapt and implement the technology. These are the ingredients necessary for a technology transfer.

Another, and different, approach developed by the ABT TATeam was their joint effort with Texas A & M University known as the TAMU Project. This approach was a method of urban problem identification devised and tested by Texas A & M students with the cooperation of the city of Dallas, Texas. The method consisted of four phases:

a. The first phase involved personal conversations with major city officials in a responsible and knowledgeable position. These conversations served to identify the major problem areas confronting the city and the personnel who would play a big role in implementing any solution.

b. The second phase required interviews with the people ("actors") identified in the first phase. The purpose was to further identify the problem and determine what constraints were working.

c. A "tree" structure was next developed to indicate the relationships between the various actors in the problem solving methodology or hierarchical structure of the city.

d. Finally more interviews with the personnel selected, generally at lower levels in the hierarchical structure, as having detailed knowledge of the problem areas.

Each of the above steps were documented and included in the ABT Monthly Report for May. The TAMU team found that the problem areas selected fell into two categories typified by the specifications of the desired solution. One required a technological device as a solution. The other required more research and development activity.

As a result of this program, four problems were selected for further work. Two of these problems were accepted by the IITRI Water Pollution TATeam for investigation. These two problems are currently active. The other two problems are in the solid waste management field.

It would appear that the general philosophy of operation of the TAMU project is little different from that followed by any other TATeam. However, it was different in one important respect. Students were used in the operational mode allowing them to become familiar with the city problems in a situation where they, the students, might have an impact. This experience also served as a vehicle for acquainting the students with NASA technology.

An innovative feature recently adopted by the ABT TATeam is their use of a group of consultants to provide the technical expertise in specifying alternative technologies for construction industry problems and evaluation of NASA technologies which are potentially applicable to a problem. These consultants are members of the Massachusetts Institute of Technology (MIT) Urban Systems Laboratory. This methodology will be useful in specifying those problems that are amenable to solution by application of NASA technology and has the potential of concentrating effort on generic areas. Problem definition will also benefit from this procedure. The ABT TATeam has noted that problem definition is an iterative process in that endeavors to locate a solution to the original problem often lead to redefinition of that problem or to defining a new problem. The MIT consultants should be of considerable assistance in this activity.

The Solution then the Problem. The SRI TATeam has been experimenting with a "technology push" transfer methodology that first locates a potential solution to a problem then attempts to locate an agency with that problem or one similar. So far, there is no documentary evidence that this methodology will work any better than any other methodology although it was initially used early in the BATeam Program. As an example of this approach, personnel of the Goddard Space Flight Center suggested to SRI that fiber optics could be adapted to a new and better rear view device for automobiles. The suggestion was further developed and presented to the National Highway Transportation Safety Board who indicated some interest. A prototype is planned for demonstration at some future time. Another example is a metal detecting system developed by the Ames Research Center. The system is directly applicable to the problem of detecting weapons on persons entering aircraft or restricted areas. A preliminary test arranged for officials of San Mateo County in California generated further interest. A several month in-use test is being arranged for the County Courthouse.

TABLE 4

PROBLEM ACCEPTANCE CRITERIA ESTABLISHED
BY EACH TATEAM

| | CRITERIA | TEAM USING CRITERIA RTI | IITRI | SRI* | ABT |
|---|---|---|---|---|---|
| 1. | Does the problem need technology or is it one which could be resolved by management? | | X | | |
| 2. | Does the problem originator consider its solution important or is it in the "nice to have" category? | | X | | |
| 3. | Is the problem of national or regional importance or is it merely of local concern to the problem originator? | | X | | |
| 4. | Is a solution to the problem within the bounds of current technology, or must it await a major advance? Probably of relevant NASA technology? | X | X | | X |
| 5. | Does the problem call for the application of new technology or is it just a question of a re-design of existing equipment? | | X | | |
| 6. | If aerospace technology yields a solution, will it necessitate a major change in the user's methods of operation which he is unlikely to accept? | | X | | |
| 7. | Can the problem be solved by the application of discrete technology or does it call for considerable research of a systems nature? | X | X | | |
| 8. | Does it appear that a solution is feasible using the TATeam methodology or does the problem suggest that it could be answered by a literature search - best performed by the RDCs? | X | X | | |
| 9. | No solution is available on the commercial market (implied in 5 above) | X | | | |
| 10. | Appear relevant to aerospace technology (implied in 4 above) | X | X | | X |
| 11. | Market potential - would a solved problem have a larger than average, above average, average, below average, or poor market? | | | | X |
| 12. | Specificity of the problem. | | | | X |
| 13. | Market feasibility - availability of a market instrument or institution capable of marketing the innovation. | | | | X |
| 14. | In the ABT experiment, the product of 4, 11, 12, and 13. | | | | X |

*SRI has not stated their criteria.

The fact that one team does or does not use any one or all of the above criteria can not be cited as good or bad. It goes without saying that some of these criteria are implicit in the program. By being in the program a team uses these criteria although they have not listed them.

Prompting a Problem. The IITRI TATeam has developed an interesting concept for use in contacting former Problem Originators when in the market for new problems. In their experience, they have found that often the former Problem Originator was unable to develop new problems once a potential solution had been offered to his original problem. IITRI believes that thorough knowledge of an organization and their major problem areas can be used to prompt the Problem Originator into recognizing and defining additional problems. In some public sector problem areas, knowledge of technological potential may be required to make a Problem Originator aware that he can improve on his present techniques.

## DATA BANK SEARCHING

Two significant events occurred during the reporting period to reflect improvements in the data bank search methodology. The first of these was the increased availability to the teams of the NASA Scientific and Technical Information Facility (STIF). While there is no evidence as yet that the resulting literature searches are superior to those performed by the Regional Dissemination Centers (RDC), there is a faster turn around time at STIF. This, together with the extremely personalized service currently provided, enable the teams to secure individual attention for their problem.

The second event was the study of literature search methods by Dr. W.H. Clingman. The principal purpose of the study was to investigate, impartially, the techniques and strategies used by the RDC's. A reason for this was team complaints over search results and the obvious variations in searches by different RDC's. A partial reason for these variations is that the RDC's attempt to provide their industrial clients with a technology match directly related to the need whereas the TATeams need technology that may be only remotely related to the need or may not have any relationship. For example, the indented writing detector described earlier was initially developed for NASA to detect imperfections in flared tubing. In that mode it had no one-to-one relationship to the law enforcement requirement. Searching for technology in the data bank is thus difficult, particularly so since the indexing system used relates the stored technology primarily to aerospace applications. IITRI has commented that only one potential transfer (out of eight) resulted from an RDC literature search.

Several alternative methods were suggested for improving the quality of the searches. These were:

a. Use of available documents from manual searches to obtain more and better descriptors.

b. Use of three separate parallel or sequential searches from one or more RDC's (three individuals each devising strategy and combine duplicates).

c. Use of increased number of synonyms to obtain generic type searches.

## NASA CENTER RESPONSE TO PROBLEM STATEMENTS

In May SRI developed a philosophy concerning relations with the NASA Field Centers in respect to the circulated problem statements. SRI said this was the one

area over which they had little control. The reason for this is that the individual field center scientist must be inspired, after reading the problem statement, to do something about it. It appears to BSCP/GWU that the TATeam does have some control here. The problem statement must be so constructed that the scientist will feel a compulsion to reply. It is obvious from the results that we have not yet developed the ultimate in problem statements.

A valid point is that the field center scientist's loyalties lie with the center. He works for the center and the TAT program is just an additional effort to be looked at if time permits. This latter thought was complicated by an initial tremendous flood of TATeam problem statements. Again, obviously some new means of gaining access to the scientist and the technology needs to be developed. Several means have been tried. One of the more successful, and one which has been tried by all TATeams to some extent, has been to locate specific NASA scientists and engineers with backgrounds or work experience directly related to a problem and then obtain TUO permission for direct dealings with this person. The object here is to eliminate the written problem statement and to develop a personal relationship. This would appear to be a prerequisite for an effective interchange leading to a potential solution to a problem. One example of this type of relationship is that of the ABT TATeam and Dr. John Parker of ARC. Their information interchange on intumescent paints and fire retardant foams has been outstanding.

A major complaint with field center responses is the lack of specificity of the response. In addition, it is questionable that the respondee, in many cases, understands what is desired of him. By this is meant a lack of understanding of the TAT program, what it seeks to accomplish, how detailed and how specific the answer should be, how to communicate with the TATeam (although this is always contained on the statement), and the form or format of the reply.

Table 5 indicates the number of responses by Field Center since March 1970.

TABLE 5

NASA CENTER RESPONSE TO TAT PROBLEM STATEMENTS

CUMULATIVE SINCE PROGRAM START

THROUGH OCTOBER 1970

| TEAM AND ACTIVITY | NASA FIELD CENTER | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ARC | FRC | GSFC | HQ | KSC | LARC | LERC | MSC | MSFC | JPL | OTHER | TOTAL |
| RTI : AIR POLLUTION | 3 | 1 | 0 | 1 | 5 | 13 | 34 | 0 | 17 | 0 | 27* | 101 |
| : MARINE SCIENCE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 3 | 1 | 0 | 1 | 5 | 13 | 34 | 0 | 17 | 0 | 27* | 101 |
| IITRI: LAW ENFORCEMENT | 0 | 0 | 1 | 0 | 2 | 5 | 3 | 0 | 3 | 0 | 2 | 16 |
| MINE SAFETY | 8 | 0 | 2 | 3 | 0 | 11 | 8 | 1 | 3 | 1 | 0 | 37 |
| WATER POLLUTION | 1 | 0 | 0 | 0 | 1 | 5 | 3 | 0 | 0 | 0 | 0 | 10 |
| TOTAL | 9 | 0 | 3 | 3 | 3 | 21 | 14 | 1 | 6 | 1 | 2 | 63 |
| SRI : AIR POLLUTION | 0 | 0 | 3 | 0 | 13 | 4 | 8 | 0 | 1 | 0 | 9 | 38 |
| CRIMINALISTICS | 9 | 0 | 0 | 0 | 1 | 4 | 5 | 0 | 0 | 1 | 9 | 29 |
| TRANSPORTATION | 2 | 0 | 4 | 0 | 3 | 3 | 2 | 0 | 0 | 0 | 9 | 23 |
| TOTAL | 11 | 0 | 7 | 0 | 17 | 11 | 15 | 0 | 1 | 1 | 27 | 90 |
| ABT : URBAN DEVELOPMENT | 0 | 0 | 3 | 0 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 9 |
| TOTAL | 23 | 1 | 13 | 4 | 26 | 50 | 63 | 1 | 24 | 2 | 56 | 263 |

*NOT REPORTED

## TRANSFER METHODOLOGY

A significant feature of the Applications Program was the "Technology Implementation Model" developed by the ABT TATeam. The world represents a philosophy for applying technology and consists of three phases as follows:

a. The feasibility phase. The transferee decides whether it is feasible to implement the proposed solution.

b. The research and development phase. Having passed through phase one, the transferee performs the research and development required for implementation.

c. The production and marketing phase. The technology has entered production and marketing following successful research and development.

This model has been programmed and successfully test run. The ultimate objective of this model is to provide the team with a means of estimating the capability of the potential transferee to implement the proposed technology. The model is based on a number of complex but general assumptions and on the Industrial Dynamics models of Dr. Forrester of MIT.

A feature of the developing transfer methodology which we view as important is typified by ABT's recent decision to concentrate on attempts to transfer hardware versus software. ABT arrived at the conclusion that software transfers were too complex and required considerable re-engineering or re-programming. This latter is a feature for which the TATeam program has little means of devoting effort to. Even more important is the ABT decision to concentrate on generic problem solving. This is a methodology that BSCP/GWU has been advocating for a number of months. In particular, ABT has decided to no longer try to solve a number of small unrelated problems but to concentrate on major areas so that solution to sub-problems will contribute to solution of the major problem area. The specific area of ABT concentration will be life safety in urban housing. An early observation of the ABT TATeam was that there were a number of barriers to transfer of technology to the private sector construction industry. These barriers were basically jurisdictional, building codes, and union practices. It became apparent that successful transfers would be few unless a means could be found to broach these difficulties. One way this could be accomplished was to transfer the technology to an activity which has the authority to dictate the use of specific technologies. This would permit demonstration projects by forcing contractors to try new ideas. This realization has led the team away from a random approach of technology transfer to a number of competing firms and has led to a policy of working with a small number of governmental agencies with the authority to apply innovation to construction projects.

The ABT TATeam is currently working with two such agencies. One, the New York State Urban Development Corporation (UDC), is nearly autonomous. The UDC can exercise the right of eminent domain to acquire land, change zoning and building codes, and has the funds and technical expertise to accomplish its objectives. The other, the federal Department of Housing and Urban

Development (HUD), is engaged in a large program of new construction known as "Operation Breakthrough". HUD also is in a position to use new and innovative technology. It was through the association with HUD that the team decided their efforts should be concentrated in a generic area and this should be the fire safety portion of the life safety in housing area.

Another important aspect of the ABT TATeam's association with UDC and HUD is that these two agencies have the potential of accepting a potential solution in the form of a concept rather in the form of a complete "black box". This would mean that these agencies could accept innovative departures and engineer them to their own requirements.

The applications engineering portion of the transfer process has been a difficult area. As noted earlier, the preliminary transfers are in a state of applications engineering. This has been arrived at by several means. One important aspect that was learned by the IITRI TATeam was that even though the engineering costs might be small a manufacturing firm might not be willing to invest their own funds in developing a product when the market for that product was not yet defined. In this case the public agency with the problem had no funds for engineering and, although it appeared there would be a market for the product, the manufacturer would only proceed if outside funds were made available. Thus, in some cases it is necessary to find a source of applications engineering funds. This has taken several forms in the TATeam program. Currently, the Law Enforcement Assistance Administration has made funds available for one engineering solution and has tentatively agreed in principle to participate further in the program by funding demonstration projects and specific examples of technology.

The Bureau of Mines has also funded several technological innovations. In these cases the NASA technology has been demonstrated to the Bureau of Mines and a working model made available for further test and evaluation in a Bureau of Mines Laboratory. The next step is for the Bureau to negotiate with private contractors for fabrication of a unit to the Bureau's specifications.

Another federal agency has taken steps to fund an innovation but in still another way. The Federal Water Quality Administration has accepted in principle an item of NASA technology. In order to have this technology engineered to their specifications, FWQA has asked the NASA contractor who developed the technology for NASA to submit an unsolicited proposal to do so.

## CONCLUSIONS

The introductory remarks indicated that the TATeam program is in the experimental stages. This has been emphasized by the preceding discussion. While experimental, an operational philosophy is evolving slowly. A number of common experiences runs through the experimental approaches being tried by each of the four teams. Among these are the following:

a. Recognition of the importance of the generic problem versus a piecemeal approach of solving individual small unrelated problems.

b. Recognition that problem definition is difficult and may require an iterative process to arrive at "the" definition.

c. Recognition of the problems involved in developing literature search strategies and how to develop a better strategy.

d. Recognition of the fact that funds for and a capability to perform applications engineering are a necessity. These must be available from the problem originator or an associated agency. It seems apparent that in many cases the associated agency will be a federal agency with a interest in the generic problem area, for instance, the interest of LEAA in the law enforcement area.

e. Recognition that there are legal and personnel problems to be surmounted, problems which may require redirection of team efforts.

f. Recognition of the need for team participation in all phases of the transfer process up to a finalized transfer.

Although the TATeam effort has been undergoing a lengthy period of experimentation, the overall program has now reached a plateau in the learning curve such that all phases of the program are operational. This is particularly true of the processes of problem identification, technology searching and evaluation, and transfer strategy formulation. The operational aspects are functioning successfully even though experiments

The successful implementation of operational aspects of the program has led to a number of problems being categorized as preliminary transfers and an increasing number of problems will soon reach that level. These preliminary transfers represent material which will have a large impact on the various public sectors involved in this program. While true of each sector, it would appear that future successful transfers in the urban area will have the greatest visibility and probably be considered the most important to the program's future. However, at the current stage of the program, each preliminary transfer stands on its own and contributes to the fact that the program has reached the point where it may be called successful. And, as a successful program, its potential future contribution to the various public sectors is immeasurable.